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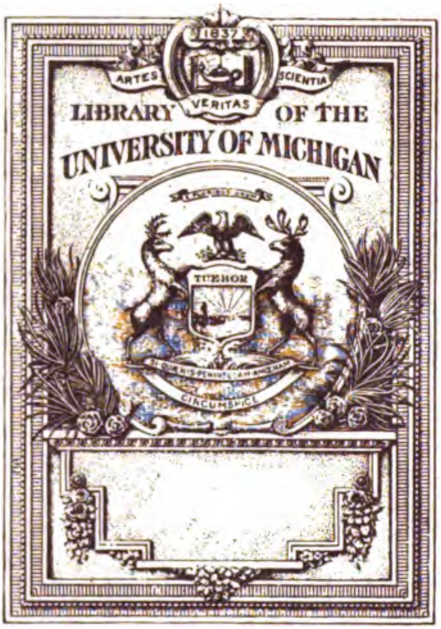

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JOURNAL OF THE UNITED STATES ARTILLERY

PUBLISHED UNDER SUPERVISION OF THE COAST ARTILLERY
TRAINING CENTER STAFF

VOLUME 51
1919

FORT MONROE, VA.
COAST ARTILLERY SCHOOL PRESS
1919

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JOURNAL OF THE UNITED STATES ARTILLERY
1919

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Numerical Integration

Efficient Technical Instruction

and a continuation of

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also

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JOURNAL OF THE UNITED STATES ARTILLERY

Published under supervision of the Coast Artillery Training Center Staff, by direction of the Chief of Coast Artillery.

12 numbers per year; volumes begin January and July. Issued on 15th day of each month.

Entered at the Post Office at Fortress Monroe, Va., as second class matter.

Subscription price, per annum:

Domestic	$3.00
Canada	3.25
Countries in the postal union	3.50
Single numbers	0.30

All subscriptions payable in advance.

Subscriptions may be entered to begin with any desired issue of the Journal. It is suggested that those who have not the numbers beginning with January, 1919, will find it desirable to begin with that issue, as all the numbers from there on are filled with especially live, important matter.

Make checks, drafts, and postal orders payable to JOURNAL U. S. ARTILLERY.

Remittances, articles intended for publication, and communications relating to the management should be addressed JOURNAL U. S. ARTILLERY, Fort Monroe, Virginia.

It is earnestly requested that prompt information be given of changes of address, or failure to receive the JOURNAL. Both old and new addresses should be given.

COLONEL R. R. WELSHIMER, C. A.
Manager and Editor
LIEUT. COL. F. S. CLARK, C. A.
Assistant Editor

London Agents:
B. F. Stevens and Brown, 4 Trafalgar Square

JOURNAL UNITED STATES ARTILLERY

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1919

The JOURNAL U. S. ARTILLERY announces the following for its annual competition.

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NOTICE

The timely importance of the report of the Board of Officers of which Brig. Gen. Westervelt was president pointed the desirability of presenting this report in full in the current number of the JOURNAL, where it will be found under the department of Professional Notes. In order to provide space for this report it has been necessary to withhold until the August number the second article in the series of three by Lt. Col. C. H. Birdsey, on High Burst Ranging.

Frontispiece

DESTROYED GERMAN GUN

2339

JOURNAL

OF THE

UNITED STATES ARTILLERY

VOL. 51, No. 1. JULY, 1919 WHOLE No. 155

The Pilot Balloon Method of Determining the Direction and Speed of the Upper Winds

By 2nd Lieut. Ivan R. Tannehill, Sig. Corps. In charge Meteorological Station, Fort Monroe, Va.

As projectiles from modern guns cover greater horizontal distances and traverse the atmosphere to increasing heights, the wind factor in firing becomes more and more important. The projectiles from the great gun which fired upon Paris at a distance of 72 miles must have reached an altitude of 35 miles or more. It has been claimed that a twelve-inch projectile weighing 870 pounds, fired as a sub-calibre from a tube inserted in a sixteen-inch gun with full service charge at an elevation of 65 degrees, will have a range of 68 miles and a maximum altitude of 48 miles.* Until recently, surface conditions were assumed to prevail throughout the path of the projectile. In general, the wind speed in lower levels is known to increase with altitude. The direction of the wind at the surface is affected by topography and is not an indication of what may be found aloft. In view of the relatively larger amount of time spent by the shell in the upper portion of the trajectory and of the great duration of flight of shells from modern guns, it is evident that upper winds greatly affect the path of the projectile. It is especially true of guns with maximum ordinates of several miles that it is necessary to know the conditions through which the projectile passes.

Roughly, the atmosphere may be divided into three layers. The surface layer extends upward to about 3000 meters. This storm layer is in constant turmoil. Above this and extending upward to 10,000 meters is an intermediate layer the normal condition of which is stability. Temperatures here decrease with altitude. From the 10,000 meter level upward to the limits of observation, the temperature increases slightly with altitude. Wind velocities, which are usually high in the layer below, drop 25 to 80 per cent on entering this layer. In recent years many sounding balloons have been sent up into this outer shell of the atmosphere. A projectile rising to a height of 48 miles would spend about 94 per cent of the total time of flight in this outer layer. It would spend approximately 70 per cent of the total time of flight beyond the height to which balloons have ever been observed. At the top of such a trajectory, the air would be so rare that it would be little more than a vacuum. These facts illustrate the widely differing conditions through which such a projectile would pass and serve to emphasize the necessity of a knowledge of those conditions.

---

*From calculations made by Jas. M. Ingalls, Col. U. S. A., retired.

It is the object of this paper to discuss methods of obtaining information as to wind movement aloft. Air density is of course an important factor in firing but the methods of obtaining it are different.

The method now used to secure wind aloft data is the observation of small pilot balloons which are allowed to drift freely in the wind. The balloon is inflated with hydrogen and its movements are observed by means of a theodolite as it rises through successive layers. The balloon picks up the horizontal motion of the air practically instantaneously and the drift of the balloon gives the wind in different layers.

These balloons are of two sizes; 6 inches and 9 inches in diameter. They are made of rubber and generally of two kinds, red and colorless. On cloudy days, red balloons are more easily observed than colorless ones. The smaller balloons are distended to a diameter of 20 to 30 inches when inflated. The nine inch balloons are inflated to 30 to 40 inches. They are then released and some of them rise to great heights before bursting.

Before inflating, the balloon is weighed. After inflating, the free lift is measured. This is the lifting force of the balloon exclusive of its own weight. The total lift is the weight of the balloon plus the free lift. Knowing the weight and the free lift of a balloon it is possible to compute its ascensional rate with considerable accuracy.

There are two ways of measuring the free lift. By the easier method, a chain is attached to the balloon. The weight of each link of the chain is known. The number of links lifted gives the free lift. By this method it is difficult to fill a balloon to any desired lift.

If it is desired to give the balloon a certain lifting force so that it will have a certain ascensional rate, the apparatus shown in Figure 1 can be used.* A hollow scale beam, A, with a nozzle at one end is balanced on a pivot at C. Directly under the nozzle hangs a pan G. D is the counterpoise. The hydrogen passes from the tank, H, into the hollow beam through a flexible hose connection at the pivot. A water manometer, B, may be connected with the hydrogen supply line through the cock, E.

The apparatus is operated as follows: The beam is balanced by means of the counterpoise before putting on either balloons or weights. Weights equal to the free lift desired are then put in the pan. The cock, E, is closed and the supply valve opened to free the tube of air. A wrench is used on the supply valve to give good control as the gas is under high pressure. The balloon should be rolled to expel all air and tied closely about the nozzle while hydrogen is

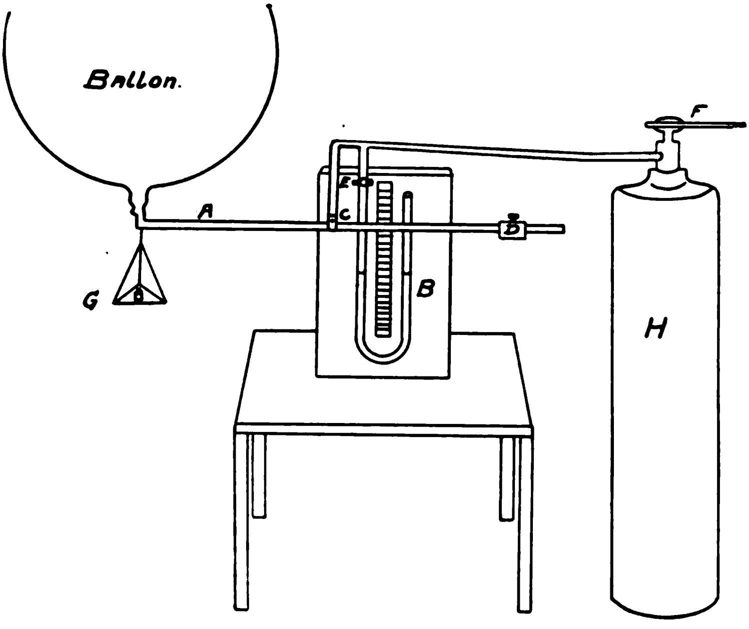

Fig. 1 2340

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*This is the apparatus used at the meteorological station at Aberdeen, Md.

slowly issuing. When the beam tips up the supply valve is closed. It is important that the balloon be filled slowly, especially in cold weather. The balloon is closed by pulling it slightly away from the nozzle and rotating it. The twisted neck is then untied and removed from the nozzle and secured by a small rubber band, wrapped around several times.

Knowing the weight of the balloon it is possible to determine from an ascensional rate formula the free lift necessary for any desired rate of ascent. If the balloon is filled and the free lift measured later, the ascensional rate is determined from formula.

Several formulas have been used in determining the ascensional rate of these balloons. The one adopted by the Meteorological Section of the Signal Corps is:

$$V = 71\left(\frac{l^3}{L^2}\right).208$$

where L is the total lift in grams, l is the free lift (total lift minus weight of balloon) in grams, and V is the rate of ascent in meters per minute. It is assumed that the balloon rises at a constant rate. There is of course a rapid initial acceleration. Within a few seconds the balloon reaches a rate of ascent which is nearly uniform,

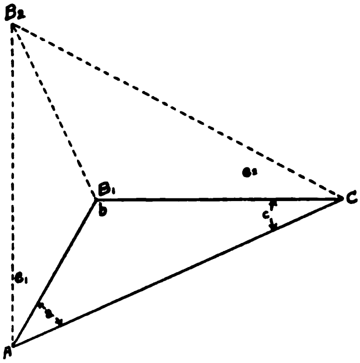

Fig. 2 2341

The balloon is observed at intervals of one minute after the time of launching. Observers with theodolites at the ends of a base line of known length read the elevation and azimuth of the balloon over the telephone to the computers and plotters in the office. By trigonometric computations or by graphical methods the path of the balloon is plotted and the altitude of the balloon at the end of each minute is determined. It is then a simple matter to obtain the velocity and direction of the wind at any level reached by the balloon.

In Figure 2, the solid lines are in the horizontal plane. The observers are at A and C and AC is the measured base line. The balloon at the end of any minute is at B_2. A perpendicular to the horizontal plane from B_2 intersects at B_1. This is the position on the horizontal plane over which the balloon lies at that instant. From the azimuth angles a and c and the distance AC we may compute the distance AB_1 or the distance CB_1.

$$AB_1 = \frac{AC \sin c}{\sin b}$$

The height of the balloon, B_1B_2, is found from the distance, AB_1, and the angle of elevation at A, e_1, by using the tangent relation.

This gives a point B_1 on the horizontal plane. At the end of the next minute another point is located. The line joining these two points is the horizontal drift of the balloon at the heights determined.

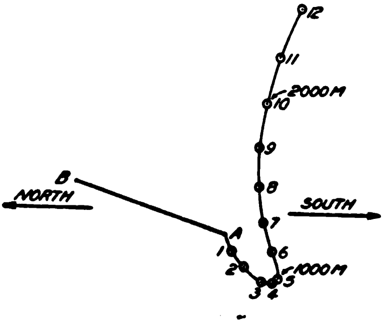

Fig. 3 2342

In plotting, the projection of the balloon's path may appear as in Figure 3. The velocity and direction of the wind is found by measuring the movement of the balloon horizontally from minute to minute.*

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*Horizontal projection of path of a balloon with surface wind northeast and a westerly wind above 1000 meters. AB is the base line. The figures 1, 2, 3, etc., refer to the number of minutes and the adjacent circled points represent the positions of the balloon at those instants.

The balloon, if raising at the rate of 200 meters per minute, will be 1000 and 2000 meters high, at the points on the projecion indicated by the arrows. The customary method of getting velocities and directions is as follows: For the 9th minute, altitude 1800 meters, the distance, in meters, traveled from the 8th to 10th minutes is measured and divided by 120, the number of seconds required to traverse this distance. The result is wind velocity in meters per second. The direction of the straight line joining the 8th and 10th positions gives the direction of the wind for the 9th minute or for an altitude of 1800 meters. The scale depends on the scale of the base line.

In actual practice graphical solutions are used. Protractors are laid off about each observation point, on the plotting board. Azimuth bars are set to the azimuth readings and the intersection represents the position of the balloon. Various devices have been used and some include an arrangement for solving for the altitude of the balloon when the distance is read off a scaled azimuth bar.

THE ONE-THEODOLITE METHOD

In cases where there are two or more observers following the balloon, it may be lost to all but one man. His readings, alone, may be employed to determine wind movement aloft with excellent results. In other cases it may be advisable to use only one theodolite in sighting a balloon. It is necessary, therefore, to have a method of obtaining results with readings from one point.

It has been learned after a great amount of experimental work that these balloons rise at a rate which is nearly uniform. After finding the weight and free lift of the balloon, the rate of ascent is computed from a formula. Probable altitudes of the balloon at the end of each minute are found. At the end of any minute, with the assumed altitude and the angle of elevation, the distance is computed from the tangent relation. The azimuth readings and the distances locate the balloon on the horizontal plot.

There are several advantages in this method. The computing and plotting require very little time. For the first few minutes of the balloon's flight, the angles shown in Figure 2, a or c, may be small, depending upon the point of release of the balloon. Again, the balloon may drift to such a distance that the base line will be so small in ratio to the distance that the two-theodolite method is not reliable. In these cases it has been claimed that the one-theodolite method is preferable.

There are objections to this method. The altitude is assumed. Even if the balloon tends to rise at a uniform rate and that rate is known, there may be vertical movements of the atmosphere which will carry the balloon higher than expected or retard its ascent. In that case the error appears as an error in distance and therefore in velocity. It also gives rise to an error in direction of the wind as deduced by this method unless the balloon is moving directly away from or towards the observation point.

Checks by the use of more than one theodolite have shown that balloons do not rise at a uniform rate. As a rule, this acceleration, whether positive or negative, is very small, relatively. Lieutenant Waterman of the Meteorological Section of the Signal Corps, after an examination of many flights with two theodolites, concludes that the acceleration depends upon the inflation. In general, balloons with a high inflation have a negative acceleration and those with a low inflation have a positive acceleration. He concludes: "The important contribution of the Fort Omaha work is that it is erroneous to assume a constant rate of ascent up to considerable altitudes unless the balloon is inflated to the proper degree." Any balloon, however, will rise to such a point, theoretically, that it will have approached its elastic limit and there will be a negative acceleration. Small balloons are usually lost before reaching this point.

The writer has made an examination of 73 balloon flights with two theodolites at Fort Monroe during the months of June, July, and August, 1918. It was found that the average ascensional rate of these balloons at the end of the fifth minute was 207 meters per minute. At the end of the tenth minute the average ascensional rate was 199 meters per minute. The average rate as computed from the formula in use at this station was 194 meters per minute. The average error in the assumed height at the end of the tenth minute was 50 meters. These balloons showed a negative acceleration which is in agreement with Lt. Waterman's conclusions since, according to his standards, these balloons were all over inflated.

Examinations of flights to 40 minutes showed the same tendency. It is safe to conclude that the ascensional rate is not uniform except in rare cases, but that the departures from that computed by formula are not large enough to cause serious errors unless there are marked convectional movements in progress.* When the flight of a balloon is plotted by both methods, the projections are very nearly coincident except in unusual conditions. However, if the greatest approach to accuracy is desired, more than one theodolite must be used.

THE TWO-THEODOLITE METHOD

The advantages of this method are obvious. The proceedure has been outlined in the foregoing.

There are objections. Even if there is more than one base line and a favorable one is chosen with reference to the direction of the wind, the balloon may drift along the base line. This may happen frequently for the wind aloft may be at right angles to that at the surface so that the observer is unable to choose a base line that willbe favorable throughout the flight. In case the balloon moves along the base line the elevation angles may be used to determine its position but this method is laborious and confusing.

THE THREE-THEODOLITE METHOD

As many as six theodolites were used in observing balloons at College Station, Texas, where Signal Corps Meteorologists were in training in the summer of 1918. Three instruments give a maximum of accuracy with an amount of labor which is not prohibitive. With three theodolites and three available base lines one of these lines would in any case be favorable.

Major Oswald Veblen, Ord. Dept., U.S.A., who visited the Proving Grounds of England and France, reported that the most satisfactory meteorological installation was that at Shoeburyness in charge of Captain E.M. Wedderhunn. They had the usual equipment of sounding balloons for the observation of wind aloft and habitually made their observations with two theodolites. They had three theodolite stations situated at the vertices of a nearly equilateral triangle of about 4000 yards to the side. This enabled them to use one pair of stations or another according to the direction of the wind.

If the men and instruments are available, it is of course better practice to have three observers stationed at the vertices of the triangle for every run. The plotter can then use all three readings or choose the two which seem most favorable at any time.

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*See Table 1.

The one-theodolite method was used, as far as can be learned, in nearly all cases in the recent war. It gives a maximum speed in plotting and balloons were usually inflated to rise at a rate of 200 or 300 meters per minute so that the work of computing was simplified. In this way much interpolation is avoided, since the drift of the balloon at any minute represents the wind movement at an altitude in even hundreds of meters.

Since it is probable that artillerymen will require data to heights that are not easily reached at the present time, suggestions are offered for improvements of methods now in use.

Larger balloons will have a higher ascensional rate and reach greater heights before being carried out of sight by the horizontal wind movement. This higher rate will be possible and still high inflation may be avoided. High inflation seems to be responsible for the bursting of the balloon at low altitudes. Theodolites with greater power will eventually be necessary.

VARIATION OF WIND ALOFT WITH VARIATION OF THE POSITION OF THE OBSERVER

For the purpose of determining the variation of wind aloft at different places, with a view to the possible desirability of making wind observations at both ends of a range, a series of simultaneous balloon flights was made at Aberdeen, Maryland. These flights were made three times daily from the 10th to the 28th of October, 1918. The two stations were approximately 25 miles apart. Two theodolites were used at both stations. See Table II.

In order to obtain the magnitude of the variation between the winds determined by the comparative flights, a value of the ballistic wind was computed from the results of each flight, assuming a straight line weighting factor curve and assuming the maximum ordinate of the trajectory to be the height attained by the balloon. These winds were compared and the mean variation in velocity was 0.82 meters per second, corresponding to a probable error of 0.69 meters per second and a probable percentage error of 7.5 per cent. The mean error in azimuth of the wind was 4 degrees. It was concluded that this error is of an unimportant magnitude when compared with the other errors in the determination of range firing data.

It is easy to demonstrate that if these data cannot be used at a point 25 miles distant from the point where they were computed, their use is questionable in any case. Suppose, for example, that the wind is 40 miles per hour from the south, as an average for all levels. We wish to fire in a southerly direction. Let the maximum ordinate be 4 miles. A balloon rising at a rate of 200 meters per minute will reach a height of 4 miles in about 35 minutes. It will be more than 20 miles north of the station when it reaches the required altitude. The data for that altitude will be computed from the drift of a balloon located more than 20 miles north of the station. Let the gun be located at the station. By the time the projectile reaches the height for which these data are used, it will be more than 5 miles south of the station. The distance between the point where the data were determined and the point where they were used is in this case more than 25 miles and the gun is located at the station.

Accuracy vs Speed

It has been said that the atmosphere in the lower levels is in constant turmoil. From day to day and hour to hour, the weather is constantly changing. At times the change is marked. At other times it changes slowly. The question is: Should we use every possible means to get absolute accuracy and so delay the delivery of the results, or should accuracy be sacrificed for speed? By using the one theodolite method and rushing the computations we may make small errors. On the other hand, during the time when we are making a long computation in order to get results with absolute accuracy, the weather may change so that our results are in error because the actual conditions have changed.

Cloudy Weather

It has been stated that the direction and velocity of the wind aloft is readily and accurately determined to heights of two miles or more on clear days. On days when the sky is clouded the balloon is lost at altitudes as low as 500 meters. It is apparent in many cases that the wind movement above the cloud level is widely different from that below the clouds.

It is important that some reliable estimate be made of conditions above the level where the balloon is lost to view.

Suppose that firing is about to begin. The sky is clouded. The pilot balloon is lost at a height of 1000 meters. The enemy, if there be one, is in exactly the same fix. Owing to the fact that upper winds do not change direction and speed as frequently as the lower, previous records are of value. Upper clouds may be visible through breaks in the lower stratum. Observations of these upper clouds are valuable. Somebody must make a guess as to the wind above the lower cloud level. The man who can make the best guess and make it quickly has the advantage. Especially is this true of long range guns, where the time spent by the projectile in the upper levels is relatively large.

At the latitude of Fort Monroe the wind tends to become westerly with increase of altitude. At heights greater than 3000 meters it is fairly safe to conclude that the wind is from some point between southwest and northwest. The velocity of the wind nearly always increases with altitude to moderate heights. These winds are much less variable than the surface wind.

When there are breaks in the lower clouds the balloon may be visible until it rises above the level of cloudiness. The cloud soon comes between the observer and the balloon, however, even when they continue to move at the same rate. It is possible under those circumstances to observe upper clouds, if there are such, and to make a reasonably accurate estimate of their velocities. Certain types of clouds are found at certain heights. If the kind of upper cloud is known and its average height is known it is a simple matter to determine the velocity. This may be done by sighting over an ordinary ruler. The number of inches on the ruler passed over by the cloud in a given time is to the distance of the ruler from the eye in inches as the number of miles covered by the cloud in that time is to the height of the cloud in miles. The clouds must be in the vicinity of the zenith for this method. Nephoscopes may be used for determining cloud speeds.

The man who plots the course of the pilot balloons from day to day and who is informed as to changes taking place in the wind aloft is the logical man to make a guess when the pilot balloon is lost in clouds. This man must study cloud movements. It has been demonstrated in the present war that a study of clouds and prevailing wind movements enables one to make a reliable forecast of the flight of a balloon. It is probable that when great haste is necessary a fairly reliable estimate of wind aloft could be made and used effectively before a pilot balloon could be inflated and launched, and certainly this can be done before the balloon reaches the required height.

Too much emphasis cannot be laid upon the necessity of having an observer who is informed as to average movements of the atmosphere aloft and who is capable of estimating cloud speeds. Guns are being developed which fire projectiles to heights above that to which pilot balloons have ever been observed. It may be a long time before soundings can be made frequently to such heights. In that case occasional soundings must be made the basis of estimates.

In the case of the great gun which fired upon Paris it must have been necessary to guess at conditions in the upper portion of the trajectory. The effect of the winds upon a projectile traversing such a distance must have been considerable. Such guns may be in general use in another war. There is a very great need, therefore, for information concerning wind movements aloft and for the training of men who can deliver the ballistic wind data in any kind of weather and to any altitude.

OTHER METHODS USED IN CLOUDY WEATHER

Major Veblen also reported concerning cloudy weather methods of obtaining wind aloft data. On both the British and American Fronts, it was customary to send up balloons to which were attached bombs with fuses so as to explode at certain altitudes. By releasing a number of balloons at the same time and obtaining the positions of the explosions by means of sound ranging apparatus, a fairly good determination of wind at various altitudes was made, according to his report.

A kite balloon was used and the direction of the wind obtained by observations on the balloon cable. The balloon also carried a Richards anemometer arranged to send by wireless a buzz at the end of every ten meters of wind. The balloon reached a height of 7000 feet.

The methods outlined in the foregoing are those which have been developed in the U. S. Army (or adopted after a study of foreign methods) since the Meteorological Service of the U. S. Signal Corps was organized a little over a year ago. There is room for improvement and many changes will be made, in all probability in the near future.

No attempt has been made to outline methods of computing the ballistic wind. The wind referred to in this paper is the true wind. Certain weighting factors are applied to the true winds and these factors vary with the type of gun and the muzzle velocity.

TABLE I

AVERAGE ERROR IN COMPUTED ASCENSIONAL RATE OF PILOT BALLOONS AT CERTAIN ALTITUDES

(All departures are negative and in meters per minute)

	Altitude in kilometers.		
Station	0.5	1.0	2.0
Fort. Monroe	20	13	5
College Station	32	23	6
Ditcham	33	20	15
Strassburg	29	20	13

These are not errors in the altitude assumed, but in the rate of ascent of the balloon as computed from formula. Departures at Ft. Monroe and College Station were from rate computed by formula

$$V = 71\left(\frac{1^3}{L^2}\right).208$$

where 1 is free lift in grams, L total lift in grams, and v rate of ascent in meters per minute.

The departures for Ditcham and Strassburg were computed by Prof. Hergesell from his formula:

$$V = \frac{A}{(A+B)^{\frac{1}{3}} - 0.8\ (A+B)^{\frac{4}{3}}}$$

where A is free lift in grams, B is total lift in grams, and v is rate of ascent in meters per minute.

TABLE II

COMPARISON OF BALLISTIC WIND RESULTS FROM SIMULTANEOUS FLIGHTS AT TWO STATIONS 25 MILES APART—SWAN POINT AND ABERDEEN, MD.

Differences in these results at the two stations include not only the variation of the actual wind between the two stations, but also include errors which may arise in the computation and the determination of the wind at either or both of the stations.

No.	Velocity—Meters Sec.			Azimuth in Degrees			Traj. Max. Ord.
	Aberdeen	Swan pt.	Diff.	Aber deen	Swan pt.	Diff.	
488	7.95	7.69	.26	150.6	151.0	.4	4152
490	8.45	8.90	.45	164.7	165.2	.5	3600
491	6.55	5.80	.75	76.3	70.7	5.6	3160
492	8.00	7.20	.80	74.2	71.6	2.6	4846
493	8.96	8.82	.14	83.8	72.4	11.4	5623
494	6.23	6.56	.33	58.1	51.1	7.0	1828
495	11.91	11.61	.30	53.0	56.5	3.5	2160
496	11.34	11.63	.29	58.3	54.5	3.8	2364
500	15.24	15.46	.22	121.6	121.3	.3	6384
501	10.52	11.36	.84	146.3	144.9	1.4	2270
502	8.74	8.50	.24	141.5	142.1	.6	1967
503	9.61	8.67	.94	130.5	136.8	6.3	2046
504	14.13	12.58	1.55	159.7	159.6	.1	3704
507	10.86	9.77	1.09	134.0	135.3	1.3	3308
508	15.44	13.54	1.90	109.6	105.1	4.5	3008
511	12.30	11.50	.80	122.5	120.8	1.7	2626
512	5.22	5.00	.22	141.4	140.3	1.1	1304
514	5.60	5.00	.60	59.1	55.7	3.4	690
515	9.80	9.70	.10	74.9	65.2	9.7	1779
516	9.56	9.10	.46	158.4	157.8	.6	2250
517	10.22	12.20	1.98	199.3	198.6	.7	855
523	4.36	4.38	.02	317.0	310.7	6.3	1770
524	8.48	9.36	.88	.4	1.4	1.0	805
525	11.60	15.60	4.00	172.9	178.7	5.8	1434
526	8.23	9.71	1.48	142.2	157.2	15.0	1830
529	15.92	16.10	.18	143.3	144.7	1.4	4402
530	11.55	11.48	.07	182.5	183.6	1.1	4800
531	9.96	9.10	.86	171.4	171.4	0.0	5242
533	7.73	7.16	.57	150.3	151.2	.9	6076
534	5.66	5.51	.15	108.9	102.5	6.4	7844
535	3.67	3.52	.15	74.4	65.0	9.4	5135
537	3.61	4.17	.56	49.3	36.3	13.0	2880
538	8.26	7.98	.28	32.6	34.0	1.4	3556
359	7.80	8.52	.72	34.4	31.0	3.4	2854
540	9.14	9.24	.10	23.0	22.4	.6	2570
541	8.00	9.97	1.97	15.3	3.0	12.3	2096
542	10.15	11.10	.95	16.7	12.4	4.3	2043

TABLE II (*continued*)

No.	Velocity—Meters Sec.			Azimuth in Degrees			Traj. Max. Ord.
	Aber-deen	Swan pt.	Diff.	Aber deen	Swan pt.	Diff.	
543	10.85	12.70	1.85	5.6	6.0	.4	1488
545	8.43	11.98	3.55	13.5	7.0	6.5	1774
546	6.86	6.52	.34	34.5	28.1	6.4	2204
547	6.03	6.32	.29	36.0	29.0	7.0	2076
549	5.80	4.32	1.48	58.9	52.3	6.6	4680
553	13.12	12.75	.37	25.0	23.5	1.5	3570
554	13.15	11.40	1.75	22.0	21.4	.6	2190
555	11.00	10.80	.20	36.1	37.6	1.5	2743
Mean	9.24	9.34	.82	95.2	93.0	4.0	3022

APPENDIX I

The following is a description of a Free Balloon Plotting Board for use in plotting the course of a free balloon, from data furnished by Lieut. Col. T. O. Humphreys, C. A. (Fig. 4.)

"A" and "B" are two observing stations.

"a" and "b" are azimuth arms set to readings from "A" and "B" on azimuth scales "f" and "g".

"S" is arch attached to "b" graduated in degrees and fractions on an arc about "B" as a center.

"e" is arm set to elevation on "S" for elevation observed from "B".

"d" (intersection of "a" and "b") is projection on a horizontal plane of position of balloon for settings of "a" and "b".

"h" is an altitude scale arm perpendicular to "b" and movable along it.

"m" is slide on "h" with stop "k" to rest against edge of "e" having on it the zero line "o" to be read on scale along "e".

"a", "b", "e" and "h" are interchangeable so that elevation can be set from "A" instead of "B".

OPERATION

Readings of azimuth coming in from "A" and "B", set "a" and "b', as in Coast Artillery plotting. Set "e" on "S" to read elevation o observed from "B". Slide "h" along "b" to intersection of "a" and "b" as shown and then slide "m" along "h" until "k" comes in contact with "e" when altitude of balloon for position "d" is read on scale on "h".

Paper is placed on board under arms and horizontal trace of balloon is plotted thereon. The altitude is read and recorded, not plotted.

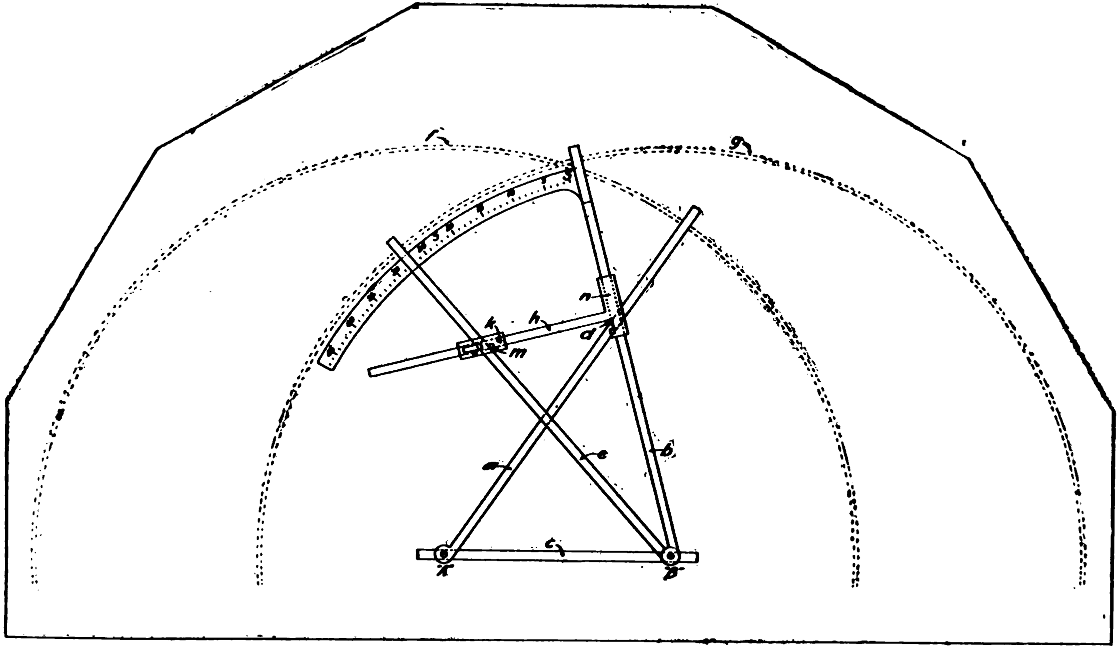


Fig. 4

Coast Defenses Constructed by the Germans on the Belgian Coast

Submitted by Major Augustus Norton, C. A. C., and Major Donald Armstrong, C. A. C.

PART II

DESCRIPTION OF BATTERIES

BATTERY DEUTSCHLAND

A four 38-cm. gun battery of the North Ostende group.

The most powerful battery on the Belgian coast was Battery Deutschland (also called Battery Jacobinessen) whose armament consisted of four 38-cm. guns on front pintle carriage with all around fire. The plan of this battery shown herewith indicates the same disposition already described for so many of the major caliber batteries. There was no continuous parapet, each gun being a separate entity with its own concrete magazine and shelter on a flank and on the same level as the loading platform. Number 1 gun had a shield which was practically a turret open at the rear with 6 cm. thickness of armor on walls and roof. The other guns were without armor protection as shown in the photographs herewith, which clearly indicates the type of emplacement without necessity for further description.

The mechanical features of the carriage are interesting and cannot be so easily detected from the photographs. Reference to these latter, however, and to the drawing of the gun carriage herewith will assist to a proper understanding of the following description. Reference should also be made to the photographs of the Leugenboom Battery herewith.

Gun.—The gun was manufactured in 1916, and is 45 calibers in length (38-cm. S.K.L. .45)

Number of grooves	100
Width of lands	6 mm.
Depth of grooves	3 mm.

Breech.—Krupp wedge system (exterior diameter 1 m. 18).

Cradle.—The gun is mounted in a cradle resting on two trunnions (diameter 45 cm.) and having underneath two hydraulic recoil cylinders and a recuperator. The trunnions rest on two cast-steel supports on the carriage.

Carriage.—The carriage is composed of a metal bridge formed by two steel plate girders, I-shaped, 2.80 m. high, and 10 m. 70 long. These beams are strongly cross-braced in front and behind.

(1) The front of the carriage rests on a ball bearing pivot, supported on a pedestal of cast-steel. The pedestal is bolted in a massive block of concrete in the center of a deep well.

(2) The rear of the carriage rests on a transversal support composed of two beams of plate steel, 3 m. 96 long, and 1m. 80 high, strongly crossbraced. The base of these beams is carried on two heavy traversing wheels, 1 m. in diameter, rolling on a circular path.

Elevating mechanism.—Laying for *elevation* is accomplished by means of an enormous inclined screw attached to the under part of the cradle and ending in a powerful sliding nut. This nut receives its movement, through a series of gears, from a shaft connected to a motor or to an elevating hand wheel.

Traversing mechanism.—Laying for *direction* is accomplished by a pinion carried in the rear support of the carriage and meshing with a traversing rack.

Laying may be effected electrically or by hand.

A system of clutches allows the movement to be communicated from the motor on each side either to the elevating or traversing mechanism. In any case the procedure is the same; the electric motor serves for large changes and the hand movement for completing the laying.

Ammunition.—The shells fired by the 38-cm are:

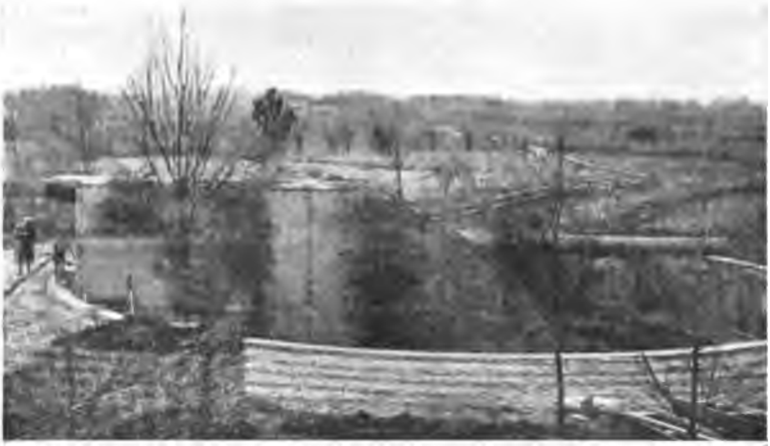
Name	Weight	Fuse	Range
H.E. 38-cm. Sp. gr............ L/4.1 Bdz. with base fuse......	750 kg.	Sp. grm. K	42 km.
H.E. 38-cm. Sp. gr............ L/3.6 m. Bdz. (m. Haube)..... with false ogive and base fuse	695 kg. 600 (without false ogive)	Sp. grm. K	44 km.
H.E. 38 cm. Sp. gr............ L 4. Bdz. u. Kz. (m. Haube) with double fuse at head and base-false ogive.....	342 kg. (without false ogive)	Sp. grm. K. and head fuse	48 km.

The charges are three in number:

(a) (Hutzenkartasche) car tridge containing 87 kg.
(b) (Vorkartusche) charge containing 96 kg.
(c) (Vorkartusche) charge containing 118 kg.

It seems then that the gun can fire with two charges, that is

(1) 87 kg. + 118 kg. = 205 kg.
(2) 87 kg. + 118 kg. + 96 kg. = 301 kg.



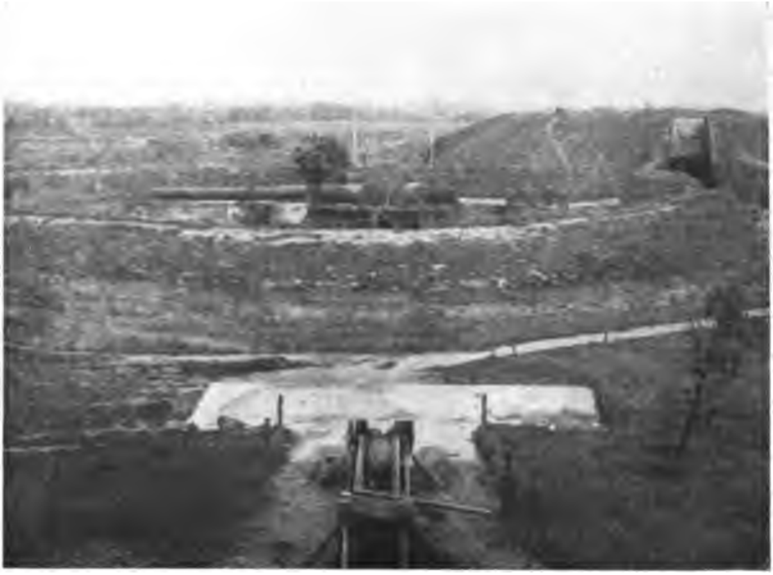
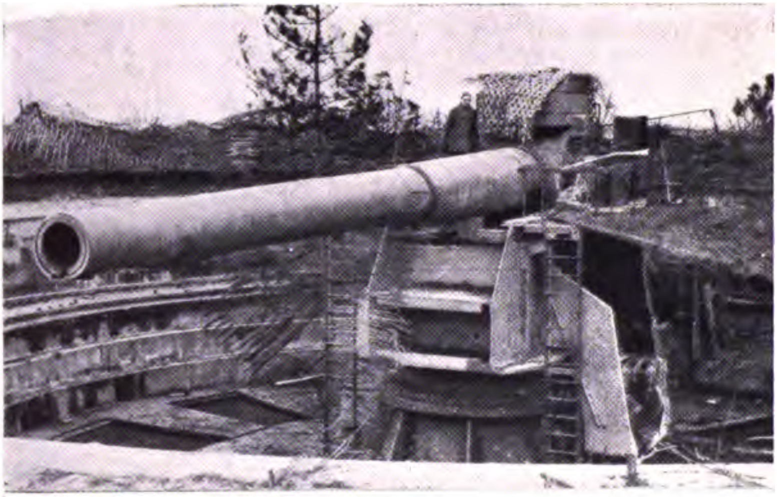


Plate 13 (Above) 2344

Battery Deutschland, 38-cm. guns. A general view of No. 1 gun and emplacement. This was the only gun with the shield mounted.

Plate 14 (Below)

Battery Deutschland, 38-cm. guns. A general view of No. 3 emplacement. The entrance to a magazine can be seen at the right of the picture.



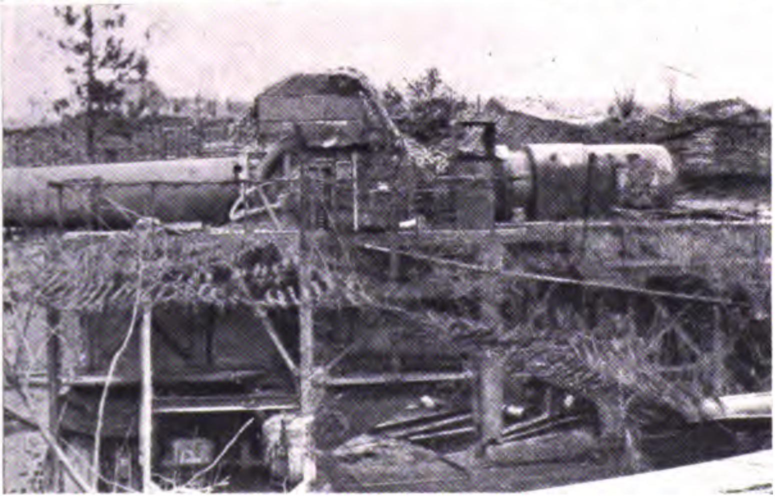
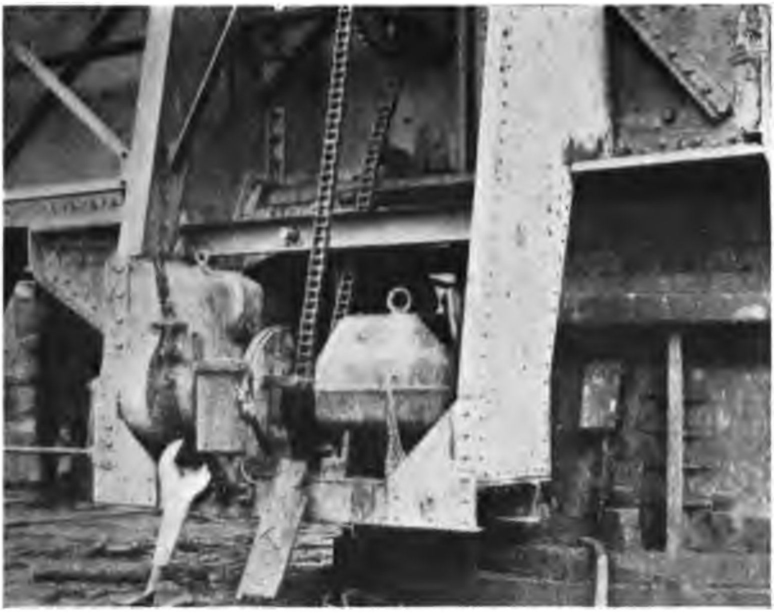


Plate 15 (Above) 2345

Battery Deutschland, 38-cm. guns. A front view of one of the guns, showing some of the details of the mounting. Note girder construction and counterpoise.

Plate 16 (Below)

Battery Deutschland, 38-cm. guns. Side view of the same piece showing some of the details of the mounting. Traversing and elevating cranks are to be seen at extreme bottom. center and right of picture. Note position of electric motor.



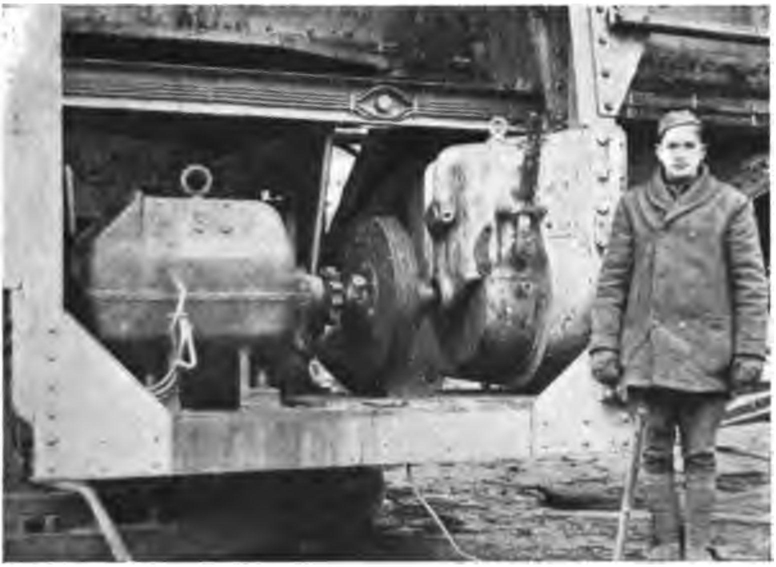
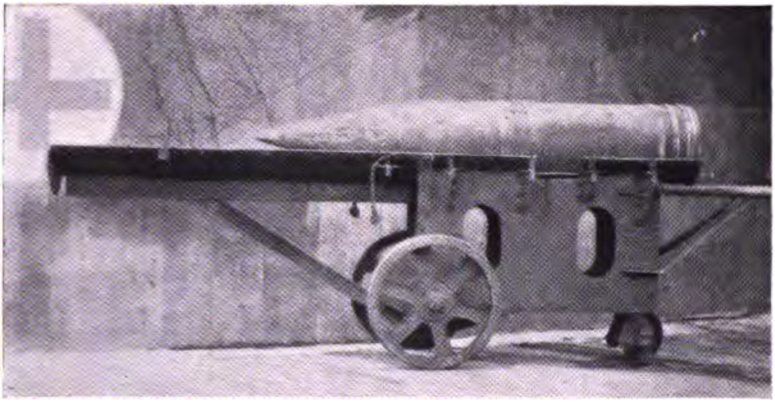


Plate 17 (Above) 2348

Battery Deutschland, 38-cm guns. A close view of the right front side of mount showing electric motor used for traversing or elevating. The chain and sprocket drives the traversing mechanism; the shaft at the top transmits power to the rear and to the traversing pinion

Plate 18 (Below)

Battery Deutschland, 38-cm. guns. A close view of the left front side of mount showing electric motor used for traversing or elevating. The elevating mechanism operates from the horizontal motor shaft. The lever shown at the right is for shifting gears. There are two speeds for elevating.



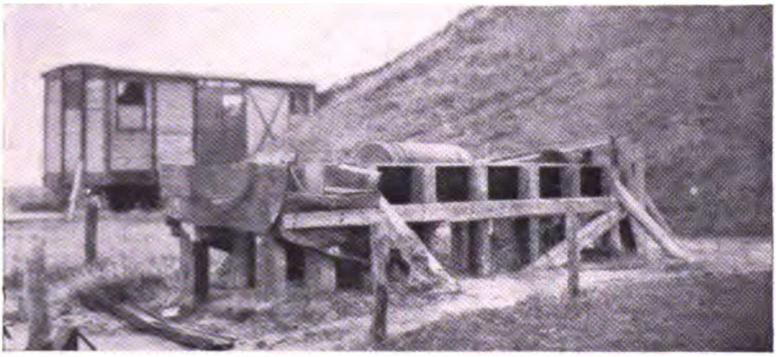


Plate 19 (Above) 2347

Battery Deutschland, 38-cm. guns. Ammunition truck with long pointed projectile. Note the three rotating bands.

Plate 20 (Below)

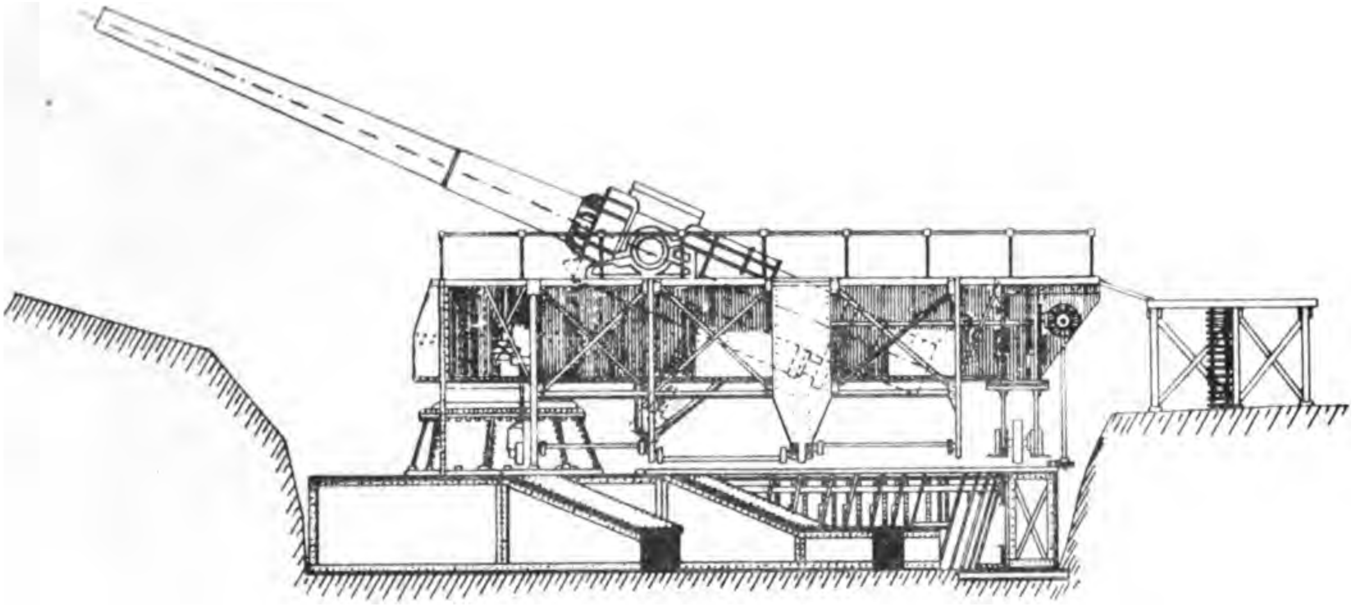
Battery Deutschland, 38-cm. guns. A device for practicing loading. Tracks for the ammunition truck are at the extreme left. A railroad car bumper is mounted at the front end of the trough.

LEUGENBOOM BATTERY

This was a single 38-cm. gun battery and is better known as "the gun that fired on Dunkirk." The Germans called it "Long Max." Whereas this battery was used exclusively against land targets, it is so intimately associated with the Coast batteries that a few remarks on Leugenboom were thought to be sufficiently revelant to be incorporated in this report.

This gun is identical with No. 1 of battery Deutschland, and therefore a repetition of the mechanical features will be omitted.

The emplacement however was constructed on a different



Battery Deutschland, 38-cm. Guns

Plate 21.

2348

Battery Deutschland, 38-cm guns. Drawing showing general construction of carriage.

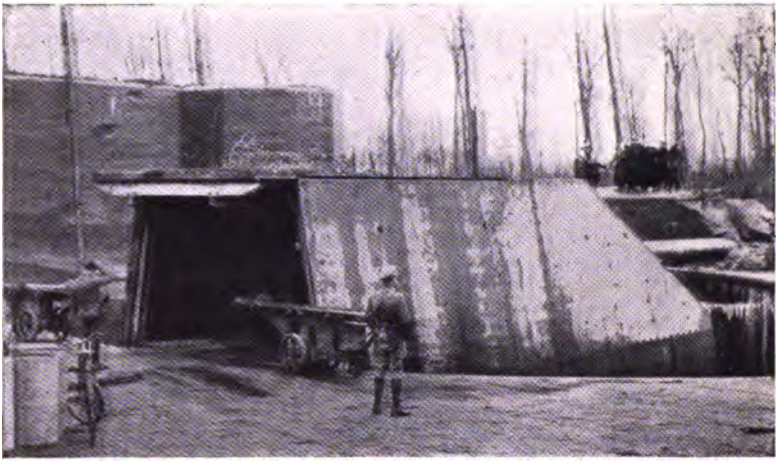


Plate 22. 2349
Leugenboom Battery, 38-cm. gun. General view of the emplacement.

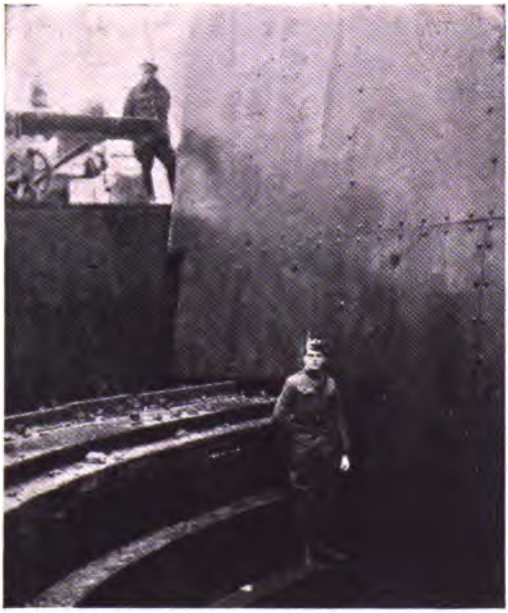


Plate 23 2350
Leugenboom Battery, 38-cm. gun. View of right side of shield. Note the size of the plates.

plan from that used at Deutschland. Firstly, the field of fire was limited to about 100 degrees and secondly, the emplacement was more extensive for a single gun. Magazines were located on either flank and were of exceptionally heavy re-inforced concrete construction.

A great many shots were fired at this battery and two direct hits were made on the emplacement, one on top of the right hand magazine and another on the loading platform not far from the entrance to the left hand magazine. Apparently the gun or carriage was not damaged and the effects on the emplacement were not severe.

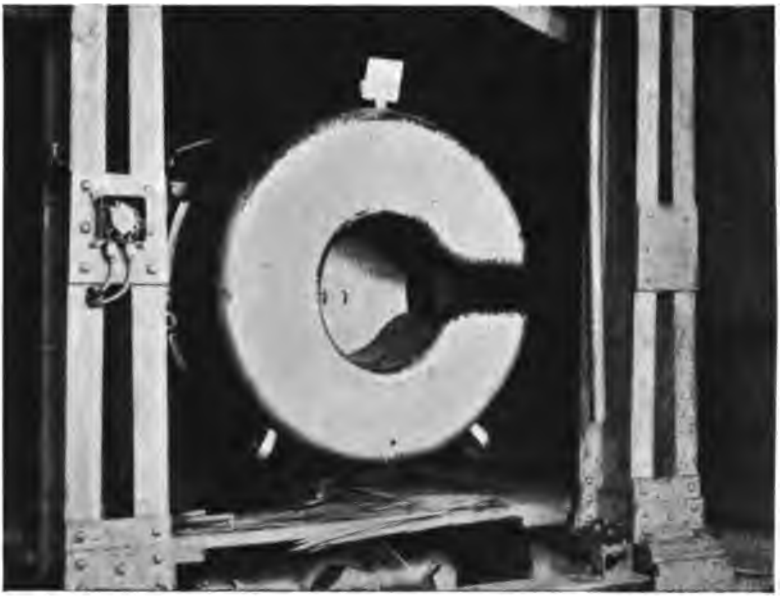


Plate 24 2351

Leugenboom Battery, 38-cm. gun. View of the breech. This gun was practically intact. Efforts to destroy this gun failed.

The P. C. of this battery was located about 200 meters on the right flank. It was unusually massive. A small power plant was also in the same structure. See Plate 8.

The Germans attempted to destroy this gun but their efforts were unsuccessful. The gun and carriage are intact and incidentally this is the only piece that was found undamaged.

BATTERY KAISER WILHELM II

A four 305-mm. gun battery of the Zeebrugge Grouping.

Kaiser Wilhelm II is similar to Battery Tirpitz which was visited first and the data on the former was not recorded.

This battery was in no way unusual. The four guns were arranged in line and except for minor details and caliber the description of Battery Tirpitz will serve.

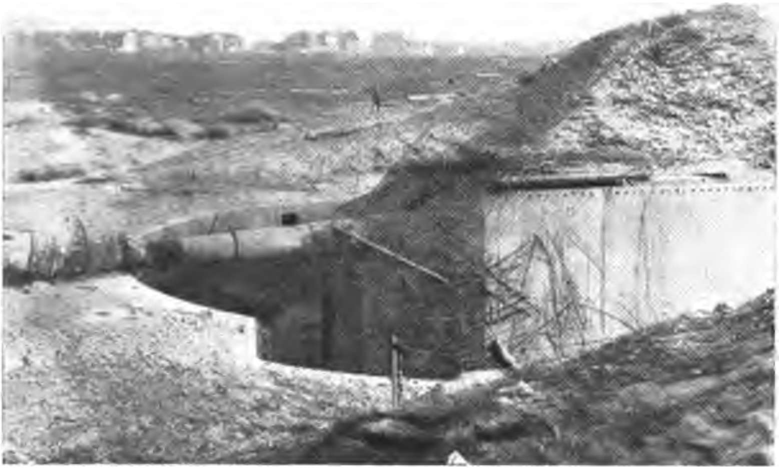


Plate 25 2352

Battery Kaiser Wilhelm II. 305-mm. guns. View of the battery from the left flank.

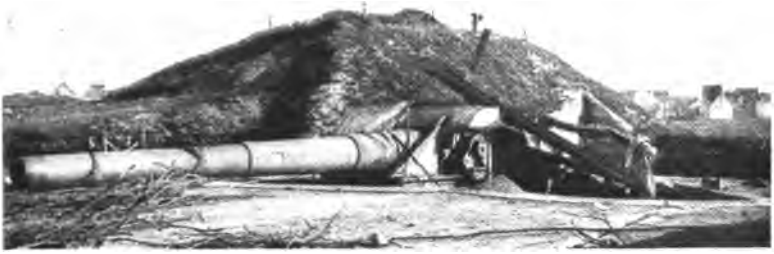


Plate 26 2353

Battery Kaiser Wilhelm II. 305-mm. guns. View of one of the pieces. Part of the shield has been blown off.

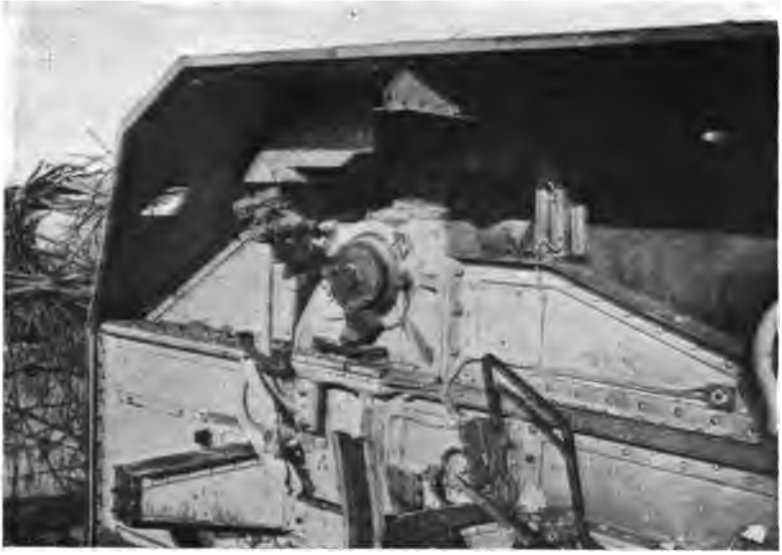


Plate 27 2354

Battery Kaiser Wilhelm II. 305-mm. guns. Close view of the left hand side of one of the carriages. Note the device on the left hand trunnion for reducing friction between trunnion and its bearing.

BATTERIES PREUSSEN AND HANNOVER

Four 28-cm. railroad gun batteries belonging to the North Ostende group.

A great part of the historical data concerning Battery Preussen has been obtained from the Bulletin de Renseignements de l'Artillerie for July, 1918. Battery Preussen, known on the Allied plan directeurs as Battery Turkigen, was first observed in a British aerial photograph of August 20, 1918. At that time, the earth-works of the two eastern emplacements were hardly outlined while the concrete work of the two western platforms was far advanced. A second photograph was taken September 27, 1918, and showed that the two emplacements to the left (West) now had their guns mounted and the eastern emplacements were apparently completed. In this same photograph a railroad gun on its mount is seen on the siding leading to the first emplacement. It apparently required about five weeks to complete the emplacements for the two pieces. The time necessary for the complete construction of the battery, including the armament and the construction of shelters and platforms apparently did not exceed three months. It further seems that if the work of construction of all four emplacements had proceeded simultaneously, the time involved would not have exceeded a month and a half.

The battery is composed of four guns, divided into two sections, each section being served by a branch of the standard gauge railway from which led tracks to each emplacement as shown in the diagram.

The disposition of the four guns of the battery, each being located at the corner of a parallelogram with the purpose of being able to utilize the four pieces in all azimuths except perhaps in that which is parallel to the small sides of the parallelogram, has already been touched upon in Part I. The guns can fire in practically every azimuth and cover the land front as well as the water areas. Each emplacement consists of an octagonal concrete platform with a circular path for the traversing wheels. A circular narrow gauge track surrounds the concrete emplacement so that ammunition can be transported to the rear of the piece regardless of its azimuth of fire.

The standard gauge track by which each piece is brought into position is prolonged beyond the concrete emplacement for the purpose of taking care of the front bogie of the railroad truck. The standard gauge track also extends over the sub-base in the center of the emplacement so that the railroad truck can be brought into its proper position.

With these facts in mind, the armament of the position is carried out in some such fashion as follows: The piece is brought into the position where its pivot is directly above the sub-base. In such position, the girder frame of the carriage is elevated by means of screw jacks, the bogies are withdrawn, one to the front, the other to the rear. The piece is then lowered on to its pivot.

Two shelters for ammunition are located between the two pieces of the same section. It is probable that one was utilized for the storage of projectiles and the other for the storage of powder. These shelters are small, being about four meters by seven meters and with a height of about eight meters. It is probable that not more than 150 shots could be stored in these magazines.

The standard gauge railroad is located on one side of this structure while on the opposite side, the narrow gauge line by which ammunition is transported to the piece, is located.

The distance from a shelter to its neighboring gun is about 60 meters, the distance between two neighboring shelters being about twenty-five meters. At some distance to the rear of this battery were concrete shelters for the personnel. About 300 meters to the east of Number 1 gun was located a battery of four anti-aircraft guns in concrete emplacements, the details of which will be given below.

It is to be noted that the lack of protection was carried to the extreme in this battery, the magazines having the thinnest possible walls and the concrete shelters in the vicinity being of somewhat lighter construction than usual. In addition, all structures were above the surface of the soil.

NOTE.—A four gun battery, referred to on the Allies' maps as Het Zoute, was under construction in February 1918 at a point about 1500 meters east of Battery Kaiser Wilhelm II. It appears as if this would be another 28-cm. R. R. gun position, but its existence was not verified.

GERMAN 28-CM. GUN ON RAILWAY MOUNT

(40 calibers—28-cm. SKL 40)

The gun is a Naval rapid fire gun of 28-cm. caliber. It is identical with the 28-cm. guns which formed part of the armament of the cruisers Naseau, Deutschland, and Braunschweig, and cruisers of the type of Goeben and Thann. The gun is carried in a cradle and mounted on girder-like chassis, the whole resting on two trucks each provided with five axles.

GENERAL INFORMATION

The piece can either be fired from its trucks on an epi or in an emplacement. In the latter case the trucks are removed and the side frames or chassis are supported in front on a circular pivot bolted to the emplacement and in rear on two large traversing wheels rolling on a traverse circle. Various ammunition wagons, etc., complete the equipment. The principal characteristics of this matériel are as follows:

Length of gun	11.22 meters (40 calibers)
Length of rifle portion	8.37 meters (29.9 calibers)
Length of powder chamber	2.5 meters
Total weight on the rails including the trucks	149.7 tons
Length of carriage without buffers	21.6 meters
Distance between the pivots of the trucks	14 meters
Load per axle	15 tons

Horizontal Field of Fire:

(a) On trucks	Unlimited (curved epi)
(b) Metallic firing platform	180 degrees
(c) On concrete firing platform as found on Belgian coast	360 degrees
(d) Maximum angle of elevation	45 degrees
(e) Minimum radius of the epi	180 meters

Description of Gun.—The gun, built by Krupp in 1904 and weighing 45,248 kg., consists of a tube, a jacket and a number of hoops. The hoop immediately in rear of trunnions carries the recoil lugs to which are attached the piston rods of the hydraulic brake, and has bearing surfaces machined on it to form the recoil guides for the gun in the cradle. The wedge breech block is rapid in its action and opens to the left. The powder chamber, 37 centimeters in diameter is joined to the bore by a centering slope from which the grooves of the rifling start. These grooves, of which there are 84, are inclined to the right with an increasing twist, the final twist of rifling being 7 degrees, 30 minutes.

Description of the Cradle.—The gun recoils in a cradle, the trunnions of which rest on the girders of the chassis. The recoil and counter-recoil system consists of a central recuperator cylinder, flanked on each side by a recoil cylinder.

A rectangular box capable of holding 4500 kilograms of metal plates, with folding sides is located on the cradle just above the trunnions. The purpose of this is to form a counter weight to facilitate elevating in the case of high angles of elevation as it increases the breech preponderance. Up to about 20 degrees, it is possible to fire without this counterweight. During travel, the plates are removed and the sides of the box are folded down so as to allow the piece to pass through the tunnel gauge.

Recoil System.—The piston rods in each recoil cylinder are hollow. On recoil, the piston heads move to the rear through the cylinders filled with liquid. A counter piston rod, screwed in the rear of each recoil cylinder carries ten grooves of varying cross section on its exterior surface. On recoil, the liquid forced back by the pistons passes into the recuperator cylinder and acts through a free piston in compressing the air of the pneumatic cylinder. All the joints are hydraulic. The pressure common to both the recoil and recuperator cylinders is 95 atmospheres. This pressure may be decreased to 85 atmospheres without causing failure in functioning of the piece. The normal length of the recoil is from 560 to 635 mm., the maximum recoil being 780 mm.

Carriage.—The chassis is composed of two heavy girders consisting of plates and angle irons riveted together, the two girders being united by transoms. The gun is mounted on trunnions in the center of these two iron girders. On the bottom of the chassis are found the central pivot and the box enclosing the two traversing wheels for use when the gun fires from its platform. The pivot is a vertical cylinder 500 mm. in diameter, attached to a circular base, 1.78 m. in diameter, which in turn, is bolted to a metallic base ring by 18 bolts fixed in the platform.

Elevating System.—"The elevating gear consists of two straight racks (not gear sectors) pivoted to the sides of the recuperator cylinders, a pinion shaft with two pinions engaging the two racks, a worm gear on the end of the pinion shaft and long handworked operating cranks, one on each side of the mount which drive the worm gear through bevel gear transmission. There is room for at least two men at each crank. The left side elevating gear has two speeds. The change of speeds is accomplished by means of a clutch. The right side has only one speed, the high speed, and final adjustments are made on the left side. The lower ends of the racks are suspended from the pinion shaft through bearings which have a partial rotation around the shaft to allow for the change in the inclination of the racks which accompanies the elevation or depression of the gun. Rollers attached to the bearing run on the under side of the rack and prevent binding. There is a ball bearing on the forward or lower end of the elevating worm. The upper end of the worm, which sustains the shock of the recoil, is not provided with ball bearing. In order to minimize the effort of elevating and depressing, it follows that the gun should be muzzle heavy or at least the muzzle preponderance when the gun is empty should be greater than the breech preponderance when it is loaded.

Traversing System.—The pedestal is carried between the the two side girders. There are four screw jacks, two on each side of the mount for lifting the mount off the front and rear trucks and depositing it on a foundation and vice versa. The pedestal turns on a ball bearing of about 2.5-m. diameter, the balls being 12- or 15-cms. The training gear for the center pivot mount is operated from the ground by a handwheel on the left side girder. The rear end of the carriage is sup-

ported by two large rollers arranged to run on a circular path with the axis of the pedestal for center. The traverse is accomplished by rotating the rollers which are connected by a train of gears to the traversing handwheel on the left side of the carriage.

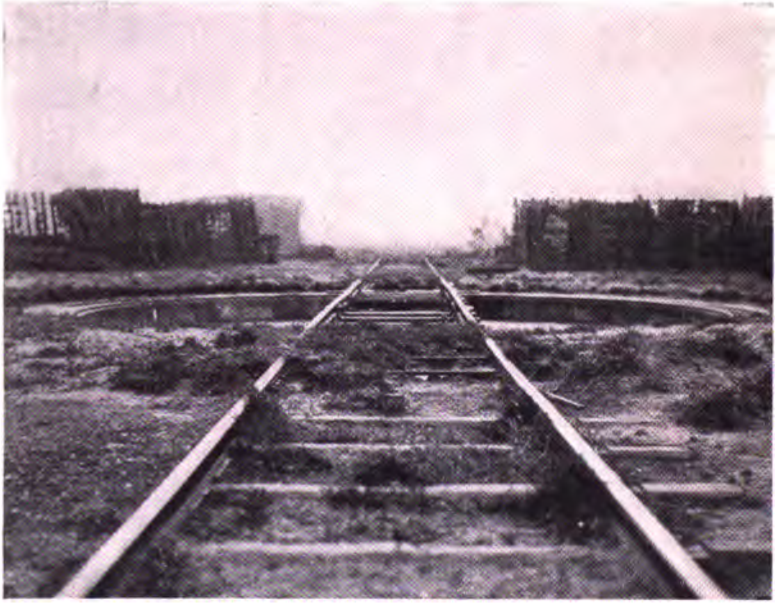
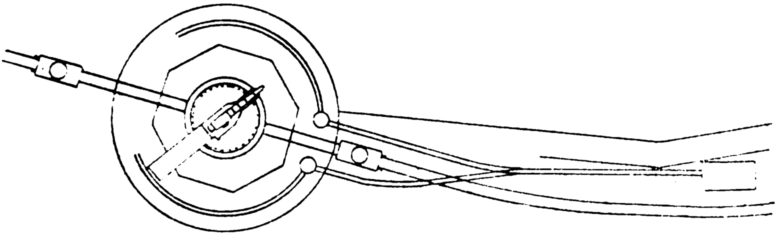


Plate 28 2355

Battery Preussen, 28-cm. R.R. guns. A view of one of the emplacements. Almost identical with Battery Hannover. The roller path is just at the edge of the shallow well.



Battery Preussen - Detail of a Platform
(Note - Battery Hannover is of the same type)

Plate 29 2356

Battery Preussen, 28-cm. R.R. Guns. Sketch showing general details of platform.

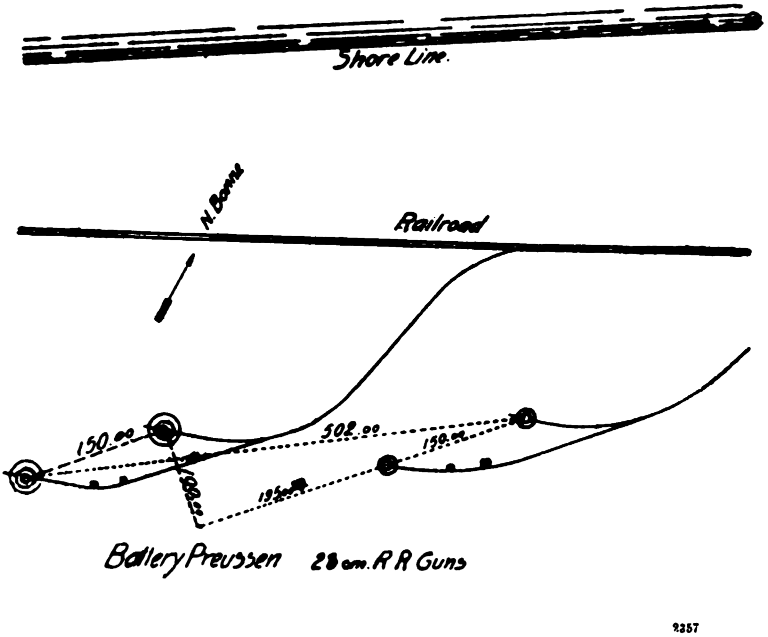
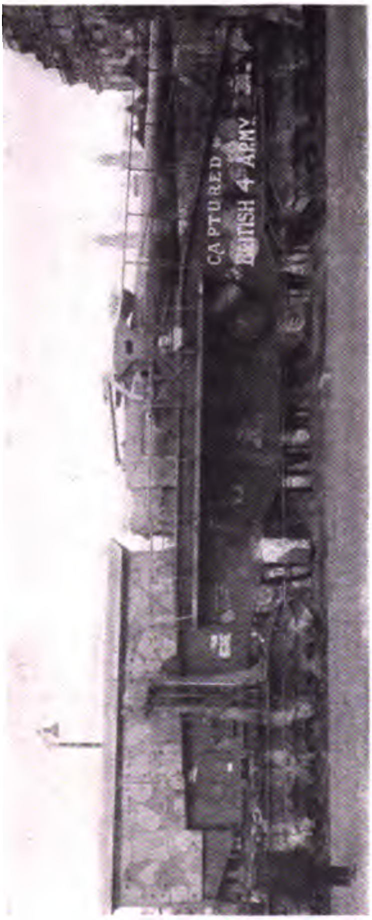


Plate 30

Battery Preussen, 28-cm. R.R. Guns. Sketch showing disposition of guns and location of magazine.



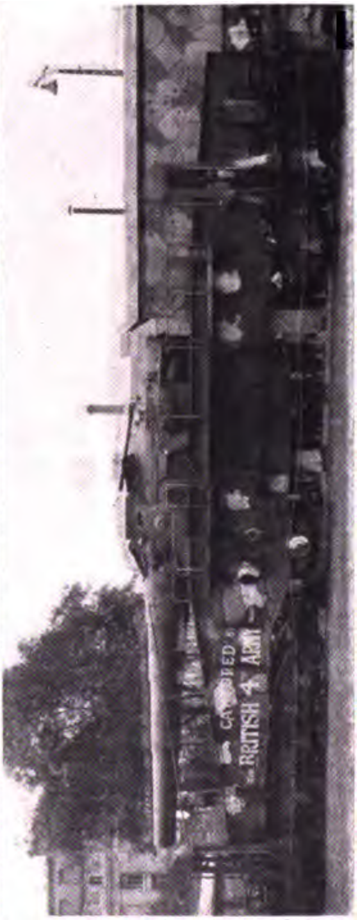
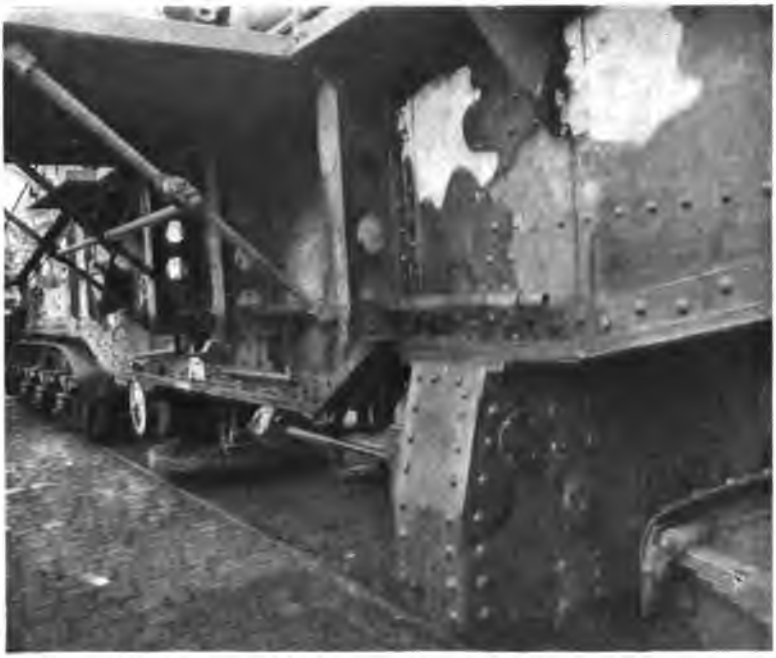


Plate 31

Plate 32

28-cm. R.R. gun. General view of gun and carriage. Right side.

28-cm. R.R. gun. General view of gun and carriage. Left side.



2359

Plate 33

28-cm. R.R. gun. Another view of left side of carriage.

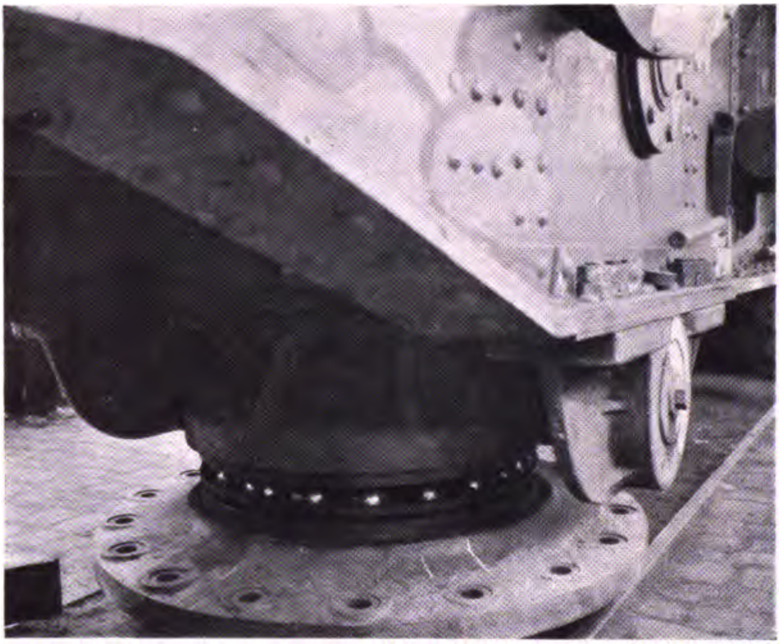


Plate 34 2360

28-cm. R. R. gun. Close view of pintle. Note the ball bearings and their size.

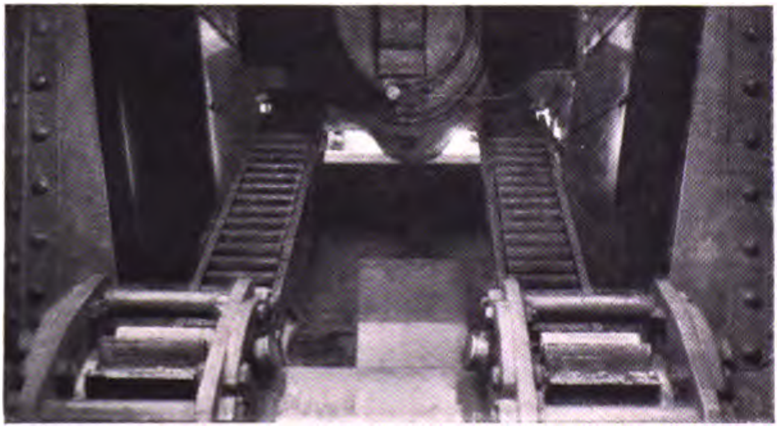


Plate 35 2361

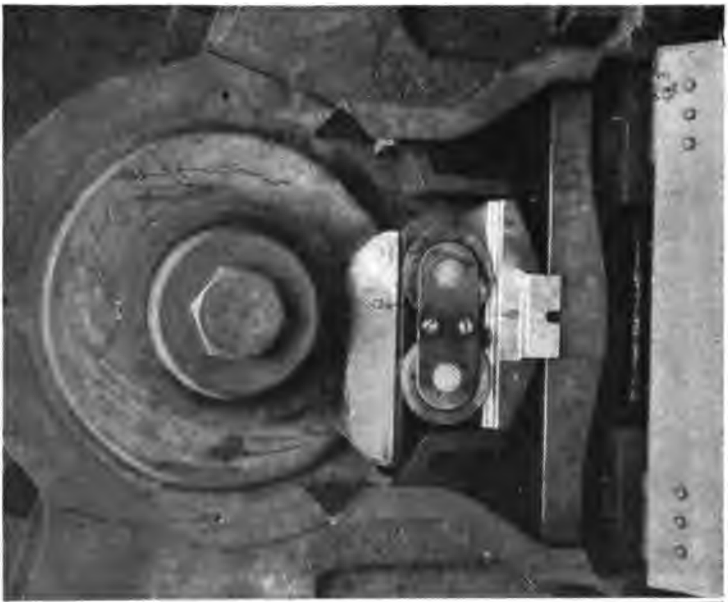
28-cm. R.R. gun. Close view of elevating racks and pinions. Note the recoil and recuperator cylinders.

Plate 36 (left)

28-cm. R.R. gun. Range scale.

Plate 37 (Right)

28-cm. R.R. gun. A detail view of the left rear side of carriage.



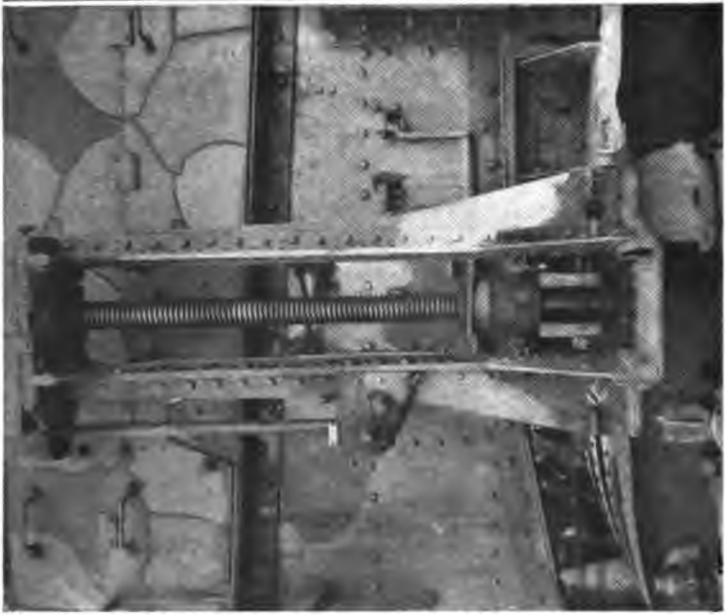


Plate 38 (left)

28-cm. R.R. gun. View showing the details of one of the four screw jacks.

Plate 40 (Right)

28-cm. R.R. gun. A view of the right hand trunnion. Note the device which serves to reduce the friction between trunnion and its bed.

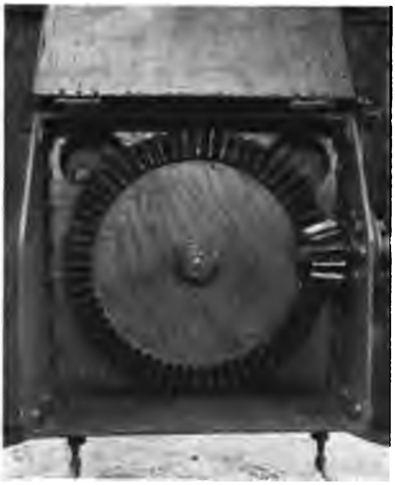


Plate 39 2364
28-cm. R.R. gun. Part of the traversing mechanism.

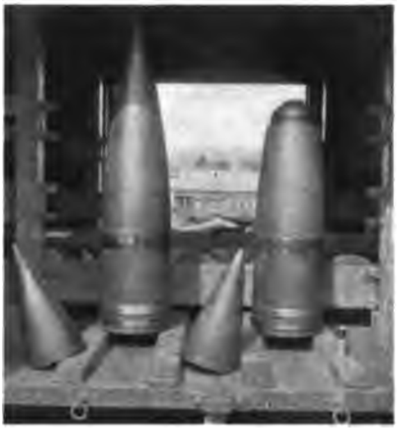


Plate 41 2365
28-cm. R.R. gun. The projectile used by this gun.

Numerical Integration of Differential Equations

By Major F. R. Moulton, Ord. Dept., U. S. A.

1. INTRODUCTION

In calculus the derivative of a function with respect to a variable on which it depends is defined as the limit of a well-known quotient, and the integral of a function is defined as the limit of a well-known sum. It is found that the processes of differentiation and integration are formally the inverses of each other. This fact leads the student at a certain stage of his study of Mathematics to suppose a definite integral, for example, can be obtained only when a function can be found whose derivative with respect to the variable of integration is the integrand. The meaning of a definite integral, however, may be given such a simple geometrical interpretation, and its real significance is so clear to the intuitions, that the student soon perceives that, under suitable conditions, a definite integral can be obtained with any required degree of approximation without any reference to the primitive of the integrand. When this stage is reached, the fact that the primitive of the integrand cannot be found is not considered as being a very serious matter.

There is an analogous situation in the case of differential equations. The subject is almost always initially developed as an outgrowth of integral calculus, and this leads to attempts to separate the variables so that the primitives can be obtained. This is, indeed, the point of view almost exclusively adopted in elementary books on differential equations, and often the student arrives at the conclusion that a differential equation cannot be solved unless its variables can be separated by some artifice. This point of view stimulates attempts to force physical laws into particular forms. It produces a bias and sometimes leads to unfortunate results. Its influence on the development of expressions for the law of resistance of a projectile in its flight through the air is very evident.

The problem of solving a differential equation, or a system of differential equations, can be considered on its own merits. In fact, it is highly desirable to do so. In particular, it should be determined under what circumstances the solutions of differential equations exist, how they may be most conveniently found, and what their properties are. These problems have all been treated by several methods in an extensive literature. Unfortunately for practice, the requirements of modern analysis make it necessary to pay much attention to delicate points of logic in which the practical man has little interest, with the result that the value of a method in applications is obscured by the theory of its correctness. Moreover, a notation that is convenient for theoretical discussions is often not most convenient for practical problems.

In this paper a method will be given for practically obtaining the solutions of ordinary differential equations. It is applicable to all differential equations which arise in actual physical problems, whether or not the variables can be separated. Moreover, it rests on a solid logical basis, which, however, will not be expounded here. It has the merit of being very convenient in practice, and it has recently been extensively used in computing trajectories. It will be illustrated at the end of this paper by a problem which can be solved otherwise.

2. Fundamental Basis of the Method

Suppose for the sake of simplicity that there are only two differential equations,

$$(1)\quad \begin{cases} \dfrac{dx}{dt} = f_1(x, y; t), \\ \dfrac{dy}{dt} = f_2(x, y; t), \end{cases}$$

where f_1 and f_2 are known functions of x, y, and t, fulfilling certain mild conditions that are always satisfied in practice. In physical problems the independent variable t does not usually appear in the right members of the differential equations.

Suppose $x = a$ and $y = b$ at $t = o$. A first approximation to x and y having these initial values is given by

$$(2)\quad \begin{cases} x_1 = a + \displaystyle\int_0^t f_1(a, b; t)\, dt, \\ y_1 = b + \displaystyle\int_0^t f_2(a, b; t)\, dt. \end{cases}$$

It will be observed that when in the integrands x and y are replaced by a and b they become known functions of t, and that, therefore, the integrals can be computed.

A second approximation is given by

$$(3)\quad \begin{cases} x_2 = a + \displaystyle\int_0^t f_1\,(x_1,\ y_1;\ t)\ dt, \\ y_2 = b + \displaystyle\int_0^t f_2\,(x_1,\ y_1;\ t)\ dt. \end{cases}$$

Since x_1 and y_1 were determined as functions of t in the first approximation, the integrands are known functions of t in this case also, and the integrals can be computed.

Suppose x_n and y_n are the nth approximation to the solution and that they have been computed; then the (n+1)st approximation is given by

$$(4)\quad \begin{cases} x_{n+1} = a + \displaystyle\int_0^t f_1\,(x_n,\ y_n;\ t)\ dt, \\ y_{n+1} = b + \displaystyle\int_0^t f_2\,(x_n,\ y_n;\ t)\ dt, \end{cases}$$

where again the integrands are known functions of t.

It is clear that it is possible to repeat this process as many times as may be desired. Three important facts have been proved about it: (a) It converges, giving definite limits x and y as n becomes infinite; (b) the limits are actually the solution of equations (1) having the required initial conditions; and (c) the solutions are continuous functions of a, b, and t. That is, if a, or b, or t is given a small variation, then the values of x and y undergo small variations.

An additional remark remains to be made. If, in the first approximation, x and y are not replaced in the integrands by a and b respectively, but by any functions of t (satisfying certain mild conditions) reducing to a and b for $t=0$, and if the process is continued as before, the solution will be obtained. If these initial functions of t are close to the final solution values of x and y, the process will converge more rapidly than when equations (2) give the first approximation.

The foregoing exposition has been given for only two differential equations, but the method is the same for any finite number of similar equations. The process in its generality is known as that of Picard, who established its logical basis about twenty-five years ago, but it had been employed in its essence by writers on Celestial Mechanics for about 150 years.

3. A GEOMETRICAL INTERPRETATION OF THE PROCESS

The interpretation of $\int_{t_1}^{t_2} f(t)\,dt$ as the area bounded by the t-axis, the curve $x = f(t)$, and the ordinates t_1 and t_2, has assisted many to an understanding of the meaning of a definite integral. Such interpretations bring the intuitions to the aid of the understanding and the reasoning powers.

A geometrical interpretation can be given of the process described in section 2. Suppose for simplicity in the graphical representation that there is but the single equation

$$(5) \qquad \frac{dx}{dt} = f\,(x, t). \quad x = a \text{ at } t = 0,$$

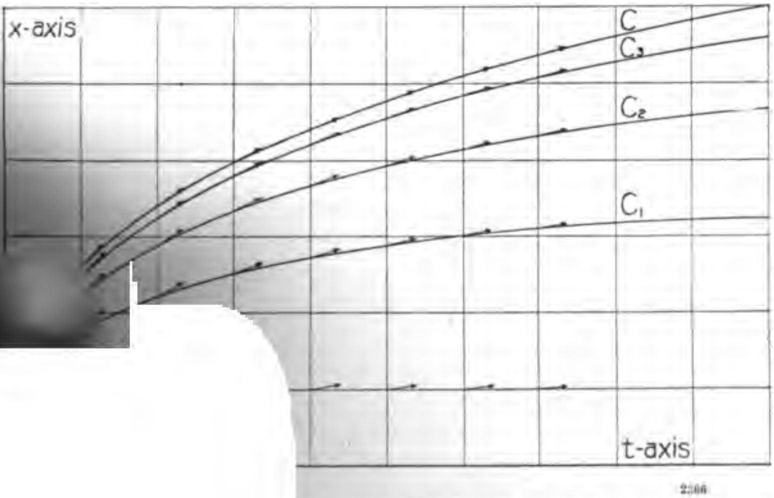
and suppose the solution is

$$(6) \qquad x = F(t).$$

Then F(t) is such a funtion that for every value of t under consideration, it is true that

$$(7) \qquad \frac{dF}{dt} = f(F, t).$$

Now consider a system of rectangular axes, the t-axis being horizontal and the x-axis vertical. For every value of x and t



se variables there is a value of f(x, t).

Suppose from each point (t,x) a short arrow is drawn in such a direction that the tangent of the angle it makes with the t-axis is f(x,t). This arrow has the direction of the tangent to the solution curve of (5) which passes through the point. In particular, the arrows which start on the solution curve C through (o,a) are all tangent to C.

The first approximation

$$x_1 = a + \int_0^t f(a, t)\, dt = F_1(t)$$

defines a curve C_1 whose tangents for every value of t under consideration are parrallel to the corresponding arrows on the line $x = a$. This conclusion is a consequence of the equation

$$\frac{dx_1}{dt} = f(a,t).$$

The second approximation

$$x_2 = a + \int_0^t f(x_1, t)\, dt = F_2(t)$$

defines a curve C_2 whose tangents are parrallel to the corresponding arrows whose origins are on the curve C_1. The succeeding approximations are similar. Upon reflection it seems highly probable, if not certain, that the curves C_1, C_2,---will approach a limit curve C unless the directions of the arrows vary from point to point in an abrupt and fantastic manner. Such is, indeed, the case.

4. COMPUTATION OF THE INTEGRALS

The integrals in (2), (3), and (4) are ordinary definite integrals. In general, the functions f_1 and f_2 will be of such a character that the primitives of the intergrands cannot be found. Let it be supposed that such is the case, for otherwise the problem is trivial.

In all methods of computing definite integrals when the primitives of the integrands cannot be found, it is necessary to compute the intergand for a number of values of the variable of integration. Consequently it is necessary to compute the values of the dependent variables in the first, second,. . .approximations for various values of t, even though only the final values are desired. This is an inconvenience which can not be avoided entirely but may often be minimized by suitable artifices. However, in many cases the value of the solution is desired for numerous, or all, values of t, and in them this circumstance is not a disadvantage. But the computation of several approximations invariably costs much labor, and their number should always be reduced as far as possible.

Two means are taken to reduce the number of approximations: (a) The solution is determined for each value of t with all the desired precision before the computation is extended to later values; (b) at each stage approximate values of the solution, which are very close to the true ones, are extrapolated from known values at earlier values of t.

Suppose the solution is known at $t_1, t_2, \ldots, t_n$ and that it is required at t_{n+1}. The work is simplified if the intervals $t_1-0, t_2-t_1, \ldots, t_{n+1}-t_n$ are all taken equal, and this is done in practice. Let the common interval be T. Then the ordinary first approximation to the solution at t_{n+1} is

$$(8)\quad \begin{cases} x_1(t_{n+1}) = x(t_n) + \displaystyle\int_{t_n}^{t_{n+1}} f_1\Big(x(t_n), y(t_n); t\Big)dt, \\ y_1(t_{n+1}) = y(t_n) + \displaystyle\int_{t_n}^{t_{n+1}} f_2\Big(x(t_n), y(t_n); t\Big)\,dt. \end{cases}$$

The result will be closer, however, if, in f_1 and f_2, $x(t_n)$ and $y(t_n)$ are replaced by functions which more nearly approximate x and y on the interval $t_{n+1}-t_n$.

Consider first the problem of finding approximate values of $x(t_{n+1})$ and $y(t_{n+1})$ from their known values at t_n, t_{n-1}, ... The functions x(t) and y(t) can be closely approximated in the neighborhood of t_n by polynomials in t, the approximation being closer the higher the degree of the polynomials and the shorter the interval. Suppose P is such a polynomial in t and that it is known for $t=t_n, t_{n-1}, \ldots,$ where $t_n-t_{n-1} = t_{n-1}-t_{n-2} = \ldots . = t_1-0=T$. Then form the first differences

$$(9)\quad \begin{cases} \Delta_1 P_1 = P(t_1)-P(0), \\ \Delta_1 P_2 = P(t_2)-P(t_1), \\ \text{-------------------} \\ \Delta_1 P_n = P(t_n)-P(t_{n-1}). \end{cases}$$

If P is linear in t, these first differences are all equal.

Now form the second differences

$$
(10)\quad \begin{cases} \Delta_2 P_2 = \Delta_1 P_2 - \Delta_1 P_1, \\ \Delta_2 P_3 = \Delta_1 P_3 - \Delta_1 P_2, \\ \text{-------------------} \\ \Delta_2 P_n = \Delta_1 P_n - \Delta_1 P_{n-1}. \end{cases}
$$

If P is of the second degree, these second differences all are equal. Succeeding differences can be formed similarly, and if P is of the mth degree in t, the mth differences all are equal.

For example, suppose P is of the third degree; then

$$
(11)\quad \begin{cases} P(0) = P(0), \\ P(t_1) = P(0) + a_1 T + a_2 T^2 + a_3 T^3, \\ P(t_2) = P(0) + a_1(2T) + a_2(2T)^2 + a_3(2T)^3, \\ P(t_3) = P(0) + a_1(3T) + a_2(3T)^2 + a_3(3T)^3, \\ P(t_4) = P(0) + a_1(4T) + a_2(4T)^2 + a_3(4T)^3, \\ \text{-----------------------------------} \end{cases}
$$

$$
\begin{cases} \Delta_1 P_1 = a_1 T + a_2 T^2 + a_3 T^3, \\ \Delta_1 P_2 = a_1 T + 3a_2 T^2 + 7a_3 T^3, \\ \Delta_1 P_3 = a_1 T + 5a_2 T^2 + 19a_3 T^3, \\ \Delta_1 P_4 = a_1 T + 7a_2 T^2 + 37a_3 T^3, \\ \text{-----------------------} \end{cases}
$$

$$
\begin{cases} \Delta_2 P_2 = 2a_2 T^2 + 6a_3 T^3, \\ \Delta_2 P_3 = 2a_2 T^2 + 12a_3 T^3, \\ \Delta_2 P_4 = 2a_2 T^2 + 18a_3 T^3, \\ \text{--------------------} \end{cases}
$$

$$
\begin{cases} \Delta_3 P_3 = 6a_3 T^3, \\ \Delta_3 P_4 = 6a_3 T^3, \\ \text{-------------} \end{cases}
$$

Suppose it is desired to approximate x and y in the neighborhood of t_n by a polynomial of the third degree, and from this polynomial to obtain approximate values of $x(t_{n+1})$ and $y(t_{n+1})$. From the values of x and y at t_n, t_{n-1}, t_{n-2}, and t_{n-3} the first, second, and third differences are formed. In the third degree polynomials the third differences will be constant, as has been remarked. Consequently

$$
(12)\quad \begin{cases} \Delta_3 x(t_{n+1}) = \Delta_3 x(t_n), \\ \\ \Delta_3 y(t_{n+1}) = \Delta_3 y(t_n). \end{cases}
$$

where the right members are known. Of course, in the actual problem the third differences at t_{n+1} will not exactly equal those at t_n. Then it follows from the way in which the differences are formed that

$$(13)\quad \begin{cases} \Delta_2 x(t_{n+1}) = \Delta_2 x(t_n) + \Delta_3 x(t_{n+1}), \\ \Delta_2 y(t_{n+1}) = \Delta_2 y(t_n) + \Delta_3 y(t_{n+1}), \\ \Delta_1 x(t_{n+1}) = \Delta_1 x(t_n) + \Delta_2 x(t_{n+1}), \\ \Delta_1 y(t_{n+1}) = \Delta_1 y(t_n) + \Delta_2 y(t_{n+1}), \\ x(t_{n+1}) = x(t_n) + \Delta_1 x(t_{n+1}), \\ y(t_{n+1}) = y(t_n) + \Delta_1 y(t_{n+1}), \end{cases}$$

in which the right members are successively known. If the intervals are suitable the values of $x(t_{n+1})$ and $y(t_{n+1})$ obtained in this way will be very close approximations to the true values.

The method suggests a convenient arrangement of the work as follows: Write the values of t in the first column and the corresponding values of x in the second column, the first differences (obtained by subtracting the upper from the lower) in the third column, the results being placed on the same lines as the minuends, the second differences in the fourth column, etc., and similarly for y. Suppose, for example, that

$$x = 3 + \frac{1}{2}t + \frac{1}{8}t^2 + \frac{1}{40}t^3 + \frac{1}{200}t^4.$$

Then the table of arguments, functional values, and differences may be arranged as follows:

t	x	$\Delta_1 x$	$\Delta_2 x$	$\Delta_3 x$
0	+3.000	-------	-------	-------
1/2	+3.285	+0.285	-------	-------
1	+3.655	+0.370	+0.085	-------
3/2	+4.141	+0.486	+0.116	+0.031
2	+4.780	+0.639	+0.153	+0.037
5/2	+5.617	+0.837	+0.198	+0.045
3	+6.697	+1.080	+0.243	-------

If it is assumed that the third difference for $t = 3$ is the same as that for $t = 5/2$, then the second difference for $t = 5$ is $+0.243$, the first difference is $+1.080$, and x is $+6.697$, as is shown in the last line of the table. The correct value of x at $t = 3$ is 6.705. That is, the extrapolated value of x is in error less than one-eighth of one per cent.

Having found approximate values of $x(t_{n+1})$ and $y(t_{n+1})$ by extrapolation, corresponding values of $f_1(x, y; t)$ and $f_2(x, y; t)$ can be computed. From the values of f_1 and f_2 at $t_{n+1}, t_n, t_{n-1}, \ldots$ it is desired to obtain very close approximations to these functions on the interval $t_n \leqq t \leqq t_{n+1}$ for use in equations (8). Suppose f_1, for example, is approximated by a polynomial of the third degree on this interval with the origin at t_n of the form

$$(14) \qquad f_1 = c_0 + c_1(t-t_n) + c_2(t-t_n)^2 + c_3(t-t_n)^3,$$

where c_0, c_1, c_2, and c_3 are constants such that the polynomial passes through the computed values of f_1 at $t = t_{n+1}$, t_n, t_{n-1}, and t_{n-2}.

Since $t_{n+1} - t_n = T$, the first of (8) becomes as a consequence of (14)

$$(15) \qquad \begin{cases} x_1(t_{n+1}) = x(t_n) + \displaystyle\int_{t_n}^{t_{n+1}} [c_0 + c_1(t-t_n) \\ \qquad\qquad + c_2(t-t_n)^2 + c_3(t-t_n)^3]dt \\ \qquad = x(t_n) + T[c_0 + \tfrac{1}{2}c_1T + \tfrac{1}{3}c_2T^2 + \tfrac{1}{4}c_3T^3.] \end{cases}$$

The coefficients c_0, c_1, c_2, and c_3 will be expressed in terms of the approximate extrapolated $f_1(t_{n+1})$ and the successive differences $\Delta_1 f_1(t_{n+1})$, $\Delta_2 f_1(t_{n+1})$, $\Delta_3 f_1(t_{n+1})$. It follows from (14) that

$$(16) \qquad \begin{cases} f_1(t_{n-2}) = c_0 - 2c_1T + 4c_2T^2 - 8c_3T^3, \\ f_1(t_{n-1}) = c_0 - c_1T + c_2T^2 - c_3T^3, \\ f_1(t_n) = c_0, \\ f_1(t_{n+1}) = c_0 + c_1T + c_2T^2 + c_3T^3, \end{cases}$$

from which $\Delta_1 f_1(t_{n+1})$, $\Delta_2 f_1(t_{n+1})$, and $\Delta_3 f_1(t_{n+1})$ can be formed, and they will be expressed linearly in terms of c_1, c_2, and c_3. The results are

$$\begin{cases} \Delta_1 f_1(t_{n+1}) = c_1T + c_2T^2 + c_3T^3, \\ \Delta_2 f_1(t_{n+1}) = 2c_2T^2, \\ \Delta_3 f_1(t_{n+1}) = 6c_3T^3, \end{cases}$$

from which it follows that

$$(17)\qquad \begin{cases} c_0 &= f_1(t_{n+1}) - c_1T - c_2T^2 - c_3T^3, \\ c_1T &= \Delta_1 f_1(t_{n+1}) - c_2T^2 - c_3T^3, \\ c_2T^2 &= \frac{1}{2}\Delta_2 f_1(t_{n+1}), \\ c_3T^3 &= \frac{1}{6}\Delta_3 f_1(t_{n+1}), \end{cases}$$

On substituting these expressions in the right member of (15) the value of $x_1(t_{n+1})$ is found to be

$$(18)\qquad x_1(t_{n+1}) = x(t_n) + T[f_1(t_{n+1}) - \frac{1}{2}\Delta_1 f_1(t_{n1+}) - \frac{1}{12}\Delta_2 f_1(t_{n+1}) - \frac{1}{24}\Delta_3 f_1(t_{n+1})],$$

and a similar expression for $y_1(t_{n+1})$. If these values of $x_1(t_{n+1})$ and $y_1(t_{n+1})$ do not differ much from the extrapolated values on which they are based, they may be adopted as the values of x and y at $t = t_{n+1}$. Otherwise $f_1(t_{n+1})$ and $f_2(t_{n+1})$ and their successive differences must be recomputed. In a practical problem tables showing how f_1 and f_2 vary for small variations in x and y enable the computer to make the slight necessary adjustments without recomputations if the interval is as short as it should be for practical purposes.

It is not necessary to use intervals of the same length in an entire computation. If the second and third differences become very small at any stage of the work, the tables may be continued after rewriting the last few entries omitting the function for alternate values of the argument. On the other hand, if the higher differences become large and irregular, it is advisable to go back a little in the computation and to interpolate values of the function for intermediate values of the argument.

5. The Start of a Computation

The method of obtaining the solution, as explained in section 4, involves a knowledge of the values of the dependent variables for several values of the independent variable. At the beginning of a computation they are, of course, known only for $t = 0$. This circumstance renders it necessary to make a few supplementary remarks.

Consider equations (1). Equations (2) give approximate values of x and y at $t = t_1$. Then first differences of f_1 and f_2 will be approximately known. Hence equations corresponding to (18) give

$$\begin{cases} x_1(t_1) = a+T\,[f_1(t_1)-\tfrac{1}{2}\Delta_1 f_1(t_1)\,], \\ y_1(t_1) = b+T\,[f_2(t_1)-\tfrac{1}{2}\Delta_1 f_2(t_1)\,]. \end{cases}$$

From these results approximate values of x (t_2) and $y(t_2)$ can be extrapolated and equations corresponding to (18) can be employed to get more accurate values of $x(t_2)$ and $y(t_2)$. Now not only first, but also second, differences are known, and $x(t_1)$ and $y(t_1)$ should be recomputed. Then $x(t_2)$, $y(t_2)$, $x(t_3)$, $y(t_3)$ can be computed using both first and second differences. The intervals should be short on the start of a computation and no further adjustments will usually be required. While the description of what to do sounds a bit complicated, the matter is really very simple in practice, particularly because, when short intervals are used, the numerical values of the differences decrease rapidly with their order, and also because the numerical multipliers in (18) are less than unity and decrease as the orders of the differences increase.

6. Application to the Computation of Trajectories

Let R represent the retardation to which a projectile is subject and note that it is backward along the tangent to the trajectory. Then, if the x-axis is taken horizontal and positive in the direction of fire, the y-axis positive upward, and if $R=Fv$, then the differential equations of motion of translation of the projectile are

$$(19)\qquad \begin{cases} \dfrac{d^2x}{dt^2} = -F\dfrac{dx}{dt}, \\ \dfrac{d^2y}{dt^2} = -F\dfrac{dy}{dt} - g. \end{cases}$$

These equations are equivalent to

$$(20)\qquad \begin{cases} \dfrac{dx}{dt} = x', \\ \dfrac{dx'}{dt} = -Fx', \\ \dfrac{dy}{dt} = y', \\ \dfrac{dy'}{dt} = -Fy'-g, \end{cases}$$

which are of the form (1) except that there are four equations instead of two.

The initial conditions are

$$x(o)=0,\ y(o)=0,\ x'(o)=x'_0,\ y'(o)=y'_0.$$

The function F has the form

$$F=\frac{G(v)\,H(y),}{C}\qquad v^2=(x^1)^2+(y^1)^2, \tag{21}$$

where G(v) is a function of v alone, H(y) is a function of y alone, and C is the ballistic coefficient. Tables of G and H with arguments v and y respectively are formed from experiment and observation, while C is supposed to be constant on a given trajectory. The variable x does not enter in the computation and may be omitted until the end, when it may be obtained from

$$x=\int_0^t x'\,dt$$

by Simpson's formula, or by any other means of obtaining the quadrature.

The time required to compute a trajectory by this method, using equations (20) or an equivalent set, depends upon the total time of flight and the accuracy with which the results are required. In the Ordnance Department the computations have usually been accurate within a few meters, and an experienced computer can calculate an ordinary trajectory with this degree of accuracy in a few hours. The results comprise not only the range and time of flight, but also all the characteristics of the trajectory. Such results are absolutely essential in anti-aircraft work, and they alone furnish an adequate basis for the treatment of the effects of winds, abnormal air densities, etc. The imperfections in the methods heretofore used were covered by making variations in the ballistic coefficient. Extensive experimental firings with two different 75 m/m anti-aircraft guns and two different 3-inch anti-aircraft guns, when compared with computations made by the foregoing methods, showed that the ballistic coefficients were constant not only along the trajectories to the maximum ordinates (the limit put by the time of burning of the fuzes) but also for all elevations up to 70°. In fact, the results were astonishingly harmonious.

7. Application to a Numerical Problem

In order to show the accuracy of the method it will be applied to a problem which can be integrated otherwise, though not simply. Suppose the differential equations are

$$(22)\quad \begin{cases} \dfrac{d^2x}{dt^2} = -\dfrac{x}{r^3}, \\ \dfrac{d^2y}{dt^2} = -\dfrac{y}{r^3}, \\ r^2 = x^2+y^2. \end{cases}$$

These are the differential equations for a particle subject to the Newtonian law of gravitation.

If the first equation of (22) is multiplied by $2\frac{dx}{dt}$, the second by $2\frac{dy}{dt}$, and if these products are added and integrated, the result is

$$(23)\quad \left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2 = \frac{2}{\sqrt{x^2+y^2}}+C.$$

The value of C is determined by the initial conditions, and equation (23) must be satisfied throughout the computation. This integral expresses the fact that the sum of the kinetic and potential energies is constant during the entire motion, and it furnishes an excellent check upon the numerical work. There is no corresponding integral in the problem of the flight of projectiles because, in this case, part of the energy is dissipated in the atmosphere.

Suppose the initial conditions for equations (22) are

$$(24)\quad \begin{cases} x(0) = 0.8, \qquad y(0) = 0, \\ x'(0) = 0, \qquad y'(0) = \sqrt{\dfrac{3}{2}}, \\ C = -1. \end{cases}$$

With these initial conditions the orbit is an ellipse with major axis unity, eccentricity 0.2, and period 2π. At $t=\pi$ the values of the co-ordinates are therefore

$$(25)\quad \begin{cases} x(\pi) = -1.2, \quad y(0) = 0. \\ x'(\pi) = 0, \quad y'(0) = -\sqrt{\dfrac{2}{3}} = -.816. \end{cases}$$

Miss Elizabeth Wilson and Miss Mabel Williard made the computations given in the following tables, which show not only the results but a convenient arrangement of the work. Table I gives the values of $-\frac{x}{r^3}, -\frac{y}{r^3}, \frac{dx}{dt}, \frac{dy}{dt}$, x, y, and their successive differences, and C at intervals of 0.1 in t.

TABLE I

t	$-x/r^3$			$-y/r^3$			x'			y'			x		y			C
0	-1.5625			0			-0.0000			1.2247			0.800		0.000			
.1	-1.5390	.0235		-.2371	-.2371		- .1561	-.1561		1.2128	-.0119		0.792	-.008	.122	.122		-1.001
.2	-1.4674	.0716	.0481	-.4618	-.2247	.0124	- .3068	-.1507	.0054	1.1777	-.0351	-.0232	0.769	-.023	.242	.120	-.002	-1.000
.3	-1.3578	.1096	.0380	-.6631	-.2013	.0234	- .4476	-.1416	.0091	1.1213	-.0564	-.0213	0.731	-.038	.357	.115	-.005	-1.001
.4	-1.2138	.1440	.0344	-.8318	-.1687	.0326	- .5765	-.1289	.0127	1.0463	-.0780	-.0216	0.680	-.051	.466	.109	-.006	- .999
.5	-1.0510	.1628	.0188	-.9642	-.1324	.0363	- .6897	-.1134	.0155	.9557	-.0906	-.0126	0.617	-.063	.566	.100	-.009	-1.000
.6	- .8769	.1741	.0113	-1.0610	-.0968	.0356	- .7862	-.0965	.0169	.8541	-.1016	-.0110	0.543	-.074	.657	.091	-.009	-1.000
.7	- .7015	.1754	.0013	-1.1239	-.0629	.0339	- .8651	-.0789	.0176	.7446	-.1095	-.0079	0.460	-.083	.737	.080	-.011	- .999
.8	- .5304	.1711	-.0043	-1.1553	-.0314	.0315	- .9267	-.0616	.0173	.6304	-.1142	-.0047	.370	-.090	.806	.069	-.011	- .999
.9	- .3701	.1603	-.0108	-1.1614	-.0061	.0253	- .9716	-.0449	.0167	.5141	-.1163	-.0021	.275	-.095	.863	.057	-.012	-1.000
1.0	- .2217	.1484	-.0119	-1.1451	.0163	.0224	-1.0011	-.0295	.0154	.3986	-.1155	.0008	.176	-.099	.909	.046	-.011	- .999
1.1	- .0886	.1331	-.0153	-1.1141	.0310	.0147	-1.0165	-.0154	.0141	.2855	-.1131	.0024	.075	-.101	.943	.034	-.012	-1.000
1.2	.0299	.1185	-.0146	-1.0704	.0437	.0127	-1.0193	-.0028	.0126	.1764	-.1091	.0040	- .027	-.102	.966	.023	-.011	-1.001
1.3	.1344	.1045	-.0140	-1.0188	.0516	.0079	-1.0110	.0083	.0111	.0719	-.1045	.0046	- .129	-.102	.978	.012	-.011	-1.000
1.4	.2247	.0903	-.0142	- .9615	.0573	.0057	- .9929	.0181	.0098	-.0272	-.0991	.0054	- .229	-.100	.980	.002	-.010	-1.001
1.5	.3024	.0777	-.0126	- .8997	.0618	.0045	- .9664	.0265	.0084	-.1203	-.0931	.0060	- .327	-.098	.973	-.007	-.009	-1.000
1.6	.3688	.0664	-.0113	- .8361	.0636	.0018	- .9327	.0337	.0072	-.2071	-.0868	.0063	- .422	-.095	.957	-.016	-.009	- .999
1.7	.4261	.0573	-.0091	- .7740	.0621	-.0015	- .8929	.0398	.0061	-.2876	-.0805	.0063	- .513	-.091	.932	-.025	-.009	-1.000
1.8	.4752	.0491	-.0082	- .7120	.0620	-.0001	- .8478	.0451	.0053	-.3619	-.0743	.0062	- .600	-.087	.899	-.033	-.008	-1.001
1.9	.5169	.0417	-.0074	- .6510	.0610	-.0010	- .7981	.0497	.0046	-.4300	-.0681	.0062	- .682	-.082	.859	-.040	-.007	-1.001
2.0	.5516	.0347	-.0070	- .5909	.0601	-.0009	- .7446	.0535	.0038	-.4921	-.0621	.0060	- .759	-.077	.813	-.046	-.006	-1.001
2.1	.5808	.0292	-.0055	- .5319	.0590	-.0011	- .6879	.0567	.0032	-.5482	-.0561	.0060	- .831	-.072	.761	-.052	-.006	-1.001
2.2	.6050	.0242	-.0050	- .4749	.0570	-.0020	- .6286	.0593	.0026	-.5985	-.0503	.0058	- .897	-.066	.704	-.057	-.005	-1.000
2.3	.6253	.0203	-.0039	- .4195	.0554	-.0016	- .5671	.0615	.0022	-.6432	-.0447	.0056	- .957	-.060	.642	-.062	-.005	-1.000
2.4	.6417	.0164	-.0039	- .3656	.0539	-.0015	- .5037	.0634	.0019	-.6824	-.0392	.0055	-1.011	-.054	.576	-.066	-.004	- .999
2.5	.6559	.0142	-.0022	- .3137	.0519	-.0020	- .4388	.0649	.0015	-.7163	-.0339	.0053	-1.058	-.047	.506	-.070	-.004	-1.000
2.6	.6668	.0109	-.0033	- .2627	.0510	-.0009	- .3726	.0662	.0013	-.7451	-.0288	.0051	-1.099	-.041	.433	-.073	-.003	- .999
2.7	.6758	.0090	-.0019	- .2130	.0497	-.0013	- .3055	.0671	.0009	-.7689	-.0238	.0050	-1.133	-.034	.357	-.076	-.003	- .999
2.8	.6831	.0073	-.0017	- .1643	.0487	-.0010	- .2375	.0680	.0009	-.7878	-.0189	.0049	-1.160	-.027	.279	-.078	-.002	- .999
2.9	.6886	.0055	-.0018	- .1161	.0482	-.0005	- .1689	.0686	.0006	-.8018	-.0140	.0049	-1.180	-.020	.199	-.080	-.002	-1.000
3.0	.6924	.0038	-.0017	- .0685	.0476	-.0006	- .0998	.0691	.0005	-.8110	-.0092	.0048	-1.193	-.013	.118	-.081	-.001	-1.001
3.1	.6934	.0010	-.0028	- .0214	.0471	-.0005	- .0305	.0693	.0002	-.8155	-.0045	.0047	-1.200	-.007	.037	-.081	- 0	-1.000
3.2	.6930	-.0004	-.0014	+ .0260	.0474	.0003	+ .0388	.0693	.0000	-.8153	..0002	.0047	-1.200	0	-.045	-.082	-.001	- .999

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Table II shows how $\frac{x}{r^3}$ and $\frac{y}{r^3}$ are computed after x and y have been found. The arrangement is such that logarithms which are to be added or subtracted are always adjacent, and so that all numbers used are written down, but written only once. The results are, of course, not obtained in the order in which they are written. After x and y have been determined the various quantities are computed in the order: $\log x$, $\log y$, $\log x^2$, $\log y^2$, x^2, y^2, $x^2+y^2=r^2$, $\log r^2$, $\log r$, $\log r^3$, $\log \frac{x}{r^3}$, $\log \frac{y}{r^3}$, $\frac{x}{r^3}$, $\frac{y}{r^3}$.

It is seen from the last entries of Table I that at $t=\pi=3.1416$ the computed values of the co-ordinates are

$$x(\pi) = -1.200, \qquad y(0) = +0.003,$$
$$x'(\pi) = +0.002, \qquad y'(0) = -0.815,$$

results which are as close to those given in (25) as could be expected from computations with only four places. The value of C given in the last column of Table I never differs by more than one unit in the third decimal from its correct value -1.000, and the fact that it oscillates throughout the computation shows that normally the accidental errors do not tend to accumulate.

TABLE II

t	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1
log x	9.90309	9.89873	9.88593	9.86392	9.83251	9.79029	9.73480	9.66276	9.56820	9.43933	9.24551	8.87506
“ r^3	9.70927	9.71150	9.71937	9.73109	9.74838	9.76867	9.79186	9.81674	9.84363	9.87104	9.89970	9.92759
“ y	0.	9.08636	9.38382	9.55267	9.66839	9.75282	9.81757	9.86747	9.90634	9.93601	9.95856	9.97451
“ x/r^3	0.19382	0.18723	0.16656	0.13283	0.08413	0.02162	9.94294	9.84602	9.72457	9.56829	9.34581	8.94747
“ y/r^3	....	9.37486	9.66145	9.82158	9.92001	9.98415	0.02571	0.05073	0.06271	0.06497	0.05886	0.04692
“ x^2	9.80618	9.79746	9.77186	9.72784	9.66502	9.58058	9.46960	9.32552	9.13640	8.87866	8.49102	7.75012
“ y^2	0.	8.17272	8.76764	9.10534	9.33678	9.50564	9.63514	9.73494	9.81268	9.87202	9.91712	9.94902
No. x^2	.6400	.6273	.5914	.5344	.4624	.3807	.2948	.2116	.1369	.0756	.0310	.0056
“ y^2	.0	.0149	.0586	.1274	.2172	.3204	.4317	.5432	.6497	.7448	.8263	.8892
“ r^2	.6400	.6422	.6500	.6618	.6796	.7011	.7265	.7548	.7866	.8204	.8573	.89483
log r^2	9.80618	9.80767	9.81291	9.82073	9.83225	9.84578	9.86124	9.87783	9.89575	9.91403	9.93313	9.95167
“ r	9.90309	9.90383	9.90645	9.91036	9.91612	9.92289	9.93062	9.93891	9.94787	9.95701	9.96656	9.9758

t	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2
log x	8.43136	9.11059	9.35984	9.51455	9.62531	9.71012	9.77815	9.83378	9.88024	9.91960	9.95276
“ r^3	9.95545	9.98224	0.00828	0.03402	0.05847	0.08066	0.10226	0.12041	0.13860	0.15555	0.17101
“ y	9.98498	9.99034	9.99123	9.98811	9.98091	9.96942	9.95376	9.93399	9.91009	9.88138	9.84757
“ x/r^3	8.47591	9.12835	9.35156	9.48053	9.56684	9.62946	9.67689	9.71337	9.74164	9.76405	9.78178
“ y/r^3	0.02953	0.00810	9.98295	9.95409	9.92244	9.88876	9.85250	9.81358	9.77149	9.72583	9.67656
“ x^2	6.86272	8.22118	8.71968	9.02910	9.25062	9.42024	9.55630	9.66756	9.76048	9.83920	9.90558
“ y^2	9.96996	9.98068	9.98246	9.97622	9.96182	9.93884	9.90752	9.86798	9.82018	9.76276	9.69514
No. x^2	.0007	.0166	.0524	.1069	.1781	.2632	.3600	.4651	.5761	.6906	.8046
“ y^2	.9332	.9565	.9604	.9467	.9158	.8686	.8082	.7379	.6610	.5791	.4956
“ r^2	.9339	.9731	1.0128	1.0536	1.0939	1.1318	1.1682	1.2030	1.2371	1.2697	1.3002
log r^2	9.97030	9.98816	0.00552	0.02268	0.03898	0.05377	0.06751	0.08027	0.09240	0.10370	0.11401
“ r	9.98515	9.99408	0.00276	0.01134	0.01949	0.02688	0.03375	0.04013	0.04620	0.05185	0.05700

t	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
log x	9.98091	0.00475	0.02449	0.04100	0.05423	0.06446	0.07188	0.07664	0.07918	0.07918
“ r^3	0.18480	0.19739	0.20764	0.21700	0.22438	0.22998	0.23391	0.23628	0.23817	0.23846
“ y	9.80754	9.76042	9.70415	9.63649	9.55267	9.44560	9.29885	9.07188	8.56820	8.65321
“ x/r^3	9.79611	9.80736	9.81685	9.82400	9.82985	9.83448	9.83797	9.84036	9.84101	9.84072
“ y/r^3	9.62274	9.56303	9.49651	9.41949	9.32829	9.21562	9.06494	8.83560	8.33003	8.41475
“ x^2	9.96182	0.00950	0.04898	0.08200	0.10846	0.12892	0.14376	0.15328	0.15836	0.15836
“ y^2	9.61508	9.52084	9.40830	9.27298	9.10534	8.89120	8.59770	8.14376	7.13640	7.30642
No. x^2	.9158	1.0221	1.1194	1.2078	1.2837	1.3456	1.3924	1.4233	1.4400	1.4400
“ y^2	.4122	.3318	.2560	.1875	.1275	.0778	.0396	.0139	.0014	.0020
“ r^2	1.3280	1.3539	1.3754	1.3953	1.4112	1.4234	1.4320	1.4372	1.4414	1.4420
log r^2	0.12320	0.13159	0.13843	0.14467	0.14959	0.15332	0.15594	0.15752	0.15878	0.15897
“ r	0.06160	0.06579	0.06921	0.07233	0.07479	0.07666	0.07797	0.07876	0.07939	0.07948

Factors Contributing to Efficient Technical Instruction

By A. A. Potter

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The following factors contribute to efficient instruction:

1. Organization

The duties of every person connected with the administration and instruction in the school should be carefully worked out, showing lines of authority and of responsibility. A diagram should then be drawn up which shows at a glance to what person each individual in the organization is responsible, and the main duties, whether executive or teaching, every person is performing. This chart should be supplemented by departmental charts and by written instructions, which should set forth details of organization.

It should be the duty of the director to familiarize the heads of the various departments with the organization and function of the school. The heads of departments should be held responsible by the director for the quality of instruction in their departments.

To correlate the work of the various instructors in any given department, frequent conferences should be held of all instructors teaching the same or related subjects. These conferences should be very informal and should aid in developing esprit de corps among the instructors, while improving teaching methods and bringing out defects in textbooks, schedules of assignment, subject matter, etc.

The director should also hold frequent conferences of all department heads in order to correlate the work of the various departments and to discuss administrative details. Matters affecting the entire school should be discussed, and important anouncements should be made at general meetings which should be attended by every person connected with the school.

When several instructors are teaching the same subject, but to different sections, the schedule of instruction should be planned by a committee including all such instructors, and in co-operation with the head of the department. If at all possible, where several instructors are handling the same subject, the sections should be arranged so that men possessing similar qualifications are assigned to the same section. Greatest aid, that is better teachers and smaller sections, should be set aside for those students of lesser ability who show a desire to make most of their opportunity. In a well organized school, every effort is always exerted to build upon a man's ability, knowledge, and experience. This means that every student is carefully tested before being assigned to any particular class, and his progress is carefully watched. ?

2 INSTRUCTORS.

The personality, ability, education, and experience of the instructors have more to do with the success of any educational institution than all other factors combined. A good instructor must have a thorough knowledge of his subject, must be familiar with the best teaching methods, must know human nature, must be able to interest and enthuse his students in the subject, while stimulating each man's imagination and developing the student's initiative, besides increasing his knowledge of the subject taught.

The personal relations, which exist between the instructor and his students, influence the results attained. An instructor, who exhibits too much superiority, will prevent students from seeking guidance at a time when such assistance will do most good. An easy-going instructor will retard the development of the students' initiative and imagination.

An instructor of technical or military subjects should have practical knowledge, in order that he may be in a position to distinguish the essential from the nonessential. On the other hand, a man with much practical experience often makes a poor instructor, as he expects too much of his students, takes too much for granted, or spends too much time in imparting specialized knowledge instead of teaching, or of developing discipline of mind so that the student can acquire knowledge by his own efforts.

A good instructor is able to talk on his feet so that he can be heard and correctly understood, and has such human qualities as to enthuse his students in the subject he is teaching.

3. Teaching Methods

Failure on the part of a student to grasp a certain subject is usually laid at the door of the student. Careful observation indicates that such failures can often be traced to poor teaching methods or to incompetent instructors.

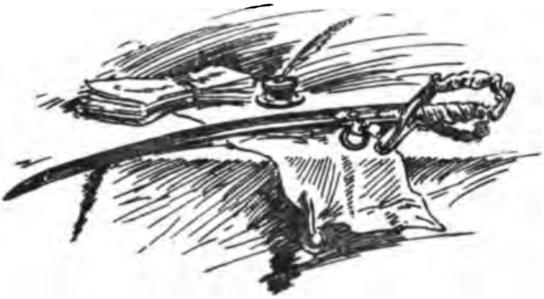
The best teaching methods lay the greatest emphasis at all times upon teaching men and not subjects. Every effort should be made to build upon a student's knowledge and experience, while stimulating his imagination and developing judgment and leadership.

Instruction cannot be efficient unless the student is interested in what he studies. To interest a student in his studies, such studies must be practical and must be imparted so that the student can see the application of the subject he studies. In technical courses, laboratory instruction should be so correlated to the classroom work that the student learns to do by doing. In the classroom, instruction lectures should be eliminated or reduced to a minimum, and in their place the recitation method should be used in connection with practical problems, so that principles are fixed in the student's mind.

In classroom work, not more than fifteen men should be assigned to one instructor, and the instruction should be planned so that each student recites every day. To save the student's time,problems bearing upon the lesson should be written out by the instructor before the time of the class and handed to each student as he enters the classroom. The student solves the problem on the blackboard, and the instructor, by watching the student's work, can find out the weak points while imparting instruction to each individual student. Not more than one-third of the classroom time should be devoted to the solution of the problems on the blackboard, and the remainder of the time should be utilized in oral discussions. In conducting an oral recitation, the instructor first asks the question before the whole class, and then calls upon one student to give the answer. This method keeps the whole class alert, which is not the case if the instructor calls upon the student and then asks him the question.

The subject matter should be carefully planned and well organized. The instruction process should consist of a series of steps or exercises taken in order, from the simple to the complex. Text book or printed notes should be used in every course, and the lesson assignments should be worked out in advance and committed to writing. Copies of the lesson schedules should be given to each student or posted, so that oral directions can be reduced to a minimum, thus conserving the student's time.

Definite organization of instructional staff and of teaching material combined with superior instructors will always result in efficient instruction.



EDITORIAL REVIEWS

THE JOURNAL AND ITS "PLACE IN THE SUN"

Happily, the JOURNAL is receiving numerous letters from subscribers, who are responding to the editorial plea which has been often voiced, to the effect that subscribers give the JOURNAL the opportunity to adjust any subscription matters gone awry on account of the war. One of these letters recently received contains the following paragraph:

> "When I was a mere 'candidate' at Monroe, before the days when even a single gold bar lent effulgence to my olive drab,—in short back in August 1917, a seductive and plausible representative of this well-known publication approached me, and by convincing me that all hope of future efficiency and advancement depended upon my becoming a subscriber to the same, succeeded in separating me from beaucoup francs for a year's subscription. Eagerly I awaited the first number. The days passed by and I sailed for France; winter, bleak and dreary, came to Mailly; spring, gentle spring arrived and with it the battlefields of Lorraine; the attack on St. Mihiel became a memory; I saw the autumn leaves fall at Angers; came the orders home, the armistice, the demobilization—now the final peace treaty, and still, and still, Oh let me say it in sorrow and grieving, still have I yet to see my first copy of the JOURNAL OF THE UNITED STATES ARTILLERY."

The readers of the JOURNAL will be relieved to know that the distress of this worthy young officer has been relieved, and that such amends as possible have been made to him for his unfortunate deprivation during the war by placing in his hands during the first year of his return to civil occupation the stimulating pages of the JOURNAL as they issue from the press. In the same spirit of accommodation the JOURNAL will attempt to adjust every claim presented to it for consideration.

However, earnest as are the intentions of the JOURNAL in this important matter, it is not for the purpose of adding emphasis thereto that the above extract is presented. It will be noted that our young veteran seemed to base his hope for "future efficiency and advancement" upon becoming a *subscriber* to the JOURNAL. Now, presumably every *subscriber* to the JOURNAL will also be a *reader*, and it is in the hope of having the JOURNAL *read* rather than merely *subscribed* to that the present management of the JOURNAL bases its only claim of service to the Coast Artillery. Far be it that we should attempt to boost the subscription list by setting forth the act of becoming a *subscriber* as a diploma of merit or as a talisman of professional advancement. Unless the contents of the JOURNAL are interesting and valuable, if not professionally indispensable, it does not deserve the support of the Coast Artillery. The JOURNAL aims to be so alive, so full of worth-while matter, and so catholic a vehicle for professional discussion that every Coast Artillery officer, old and young, will *desire* to be a subscriber. Already the practical signs point to the realization of this aim. The JOURNAL claims no "divine right" to being, and it hopes to hold a "place in the sun" only by reason of its usefulness.

The past and present loyalty of the Coast Artillery Corps to the JOURNAL is appreciated, and the continued expression of that loyalty is urged in order to make the JOURNAL measure up to its possibilities of usefulness. More subscriptions are needed to make a better paper. But more than that, the JOURNAL is yours, not only to read, but yours to write. Although at present confined to swivel chairs, the editors of the JOURNAL have been and hope again to be soldiers, and are under no illusions. Neither the editorial sanctum, nor yet Fort Monroe, are the fountains of all wisdom. The progress of the Corps will be determined in the future, as it has been in the past, by the initiative and earnest zeal of the officers bearing the burden and heat of the day,—on the job in the Coast Defenses. The JOURNAL must be able to present the results of this practical research, this ever teeming laboratory of achievement, for the use of the whole Corps, or the JOURNAL fails of its mark. The JOURNAL's "Place in the Sun" will be determined in the Coast Defenses.

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THE ENLISTED SPECIALIST

The Coast Artillery Corps is facing the future with earnestness and an open mind. As a Corps we recognize our particular fitness for certain parts of the auxiliary service essential to the successful operation of the nation's army. This particular fitness may be characterized by an ingrained regard for precision methods of fire, an inherent readiness to master the details of a great variety of artillery matériel, with an especial facility in the handling of heavy, high-powered guns, an extensive familiarity with the principles and application of electricity and mechanics, and finally a practical acquaintance with gas engines and other prime movers. The future usefulness of the Corps will largely depend upon the further development and exploitation of these characteristics. Therefore every factor in the maintenance of technical efficiency must receive its due recognition. Hitherto the Enlisted Specialist has been a most important factor in the technical efficiency of the Corps. By reason of his past and present contribution to the Corp's usefulness, as well as by reason of the rôle to be assigned him in the future, a survey of his status and a consideration of his outlook are highly in order.

The concept and creation of a body of superior, highly-trained enlisted specialists dates back less than two decades. The idea was a gradual development from the technical necessity of the Coast Artillery, in the care and operation of its increasingly complicated and varied equipment, and it may truthfully be said that the exposition of the idea was a significant contribution from the Coast Artillery to the rest of the service. Before the World War the enlisted specialists held a unique and highly respected position in the Coast Artillery Corps. For the most part they were experts in their own fields, had long years of service behind them, and commanded the respectful consideration of their officers by reason of their ability and soldierly qualities. Their status was sufficiently elevated and dignified so that other soldiers looked up to them, and their positions were worth while for the rank and file to strive for. The Coast Artillery School at Fort Monroe had established and maintained high professional standards for the different grades, and the enlisted specialists had a distinct esprit and a just pride in themselves and their Corps.

When the United States entered the war and an inconceivable expansion of the army's commissioned personnel was required, it was inevitable that such a reservoir of men of military experience and high character should be drained almost at the outset, and so it was that nearly all the enlisted specialists who would accept commissions were commissioned in different branches of the service. The body of enlisted specialists as such was practically wiped out and scattered to the proverbial four winds. In retrospect it may now be seen that many of the measures taken in the stress of a wholly unprecedented emergency were not as well advised as they might have been if decisions had not been demanded with an urgency that brooked no delays for thorough consideration. Consequently there were some former enlisted specialists who were assigned to commissioned duty for which their previous training had not specifically fitted them, and as with classes of officers from other sources, there are to be seen notable inequalities of promotion. However, the record is outstanding that an overwhelming majority of the officers who were enlisted specialists have reflected distinguished credit upon themselves and upon the Corps. They have made good.

In order to fill the gap caused by commissioning so many specialists and also to furnish additional men of special training for duty overseas, three months' emergency courses were organized at the Coast Artillery School. For the most part the men chosen for these courses were superior men with previous experience in some technical field, but with little background of military experience. They were in the service only for the war and had little concern for any prestige accruing to them as enlisted specialists, their one desire being to get to France and help win the war. Their own attitude, coupled with the inexperience of many of the officers with whom they served, resulted in a temporary decline in the appreciation accorded to the enlisted specialist. Specific instances could be mentioned where Master Electricians, Engineers, Electrician Sergeants, and Radio Sergeants were called upon to perform duties ordinarily assigned to privates. Occurrences such as these were undoubtedly attributable to the ignorance of certain officers regarding the customs of the service governing the consideration due to high ranking noncommissioned officers. The following is an extract from a personal letter recently received by an officer of Coast Artillery from a man who was a Radio Sergeant during the war, and probably the sidelight which it gives on this situation is not extreme:

> "It may please you to know that I am working with the——Electric Company, having a good position and being well satisfied with it. The only electrical experience I ever had, and I told them so when I hired out, was the training I received at Fort Monroe in the Radio School during the emergency course of the summer of nineteen eighteen. After the first month I have been given a raise in salary without asking for it. I was put in touch with the company thru the government employment agency, so must say that Uncle Sam has been looking after me all right.
>
> "Now may I offer a suggestion or rather ask a question? Why is it that

the average army officer is so ignorant in matters concerning the N.C. Staff and the regulations governing them? I was in the army over sixteen months as private, corporal and sergeant before I was made Radio Sergeant and not once in that time was I put in as humiliating a position as the staff was a dozen times in the. .th Art. C.A. The staff certainly had it put over on them and the worst of it was that there seemed to be nothing in black and white to back them up. It became quite a byword in the company we were attached to to say, 'after the company, the staff'. If there are regulations for the staff, where can they be found and why are regimental officers at least, not kept posted on them?"

This extract is presented, not in a spirit of recrimination, but rather as one of the fundamental bases of data upon which we must ground our thinking in planning to rehabilitate the body of enlisted specialists. One of the facts we must realize is that the distinctive esprit of the enlisted specialists which existed before the war, for various reasons has gone.

In planning for the future, consideration must also be given to the outlook of the former specialists who are now officers. It will take a long time to replace their technical ability and experience in the service, and the fact must be faced that very few of them will return to the status of enlisted men. A very proper pride will prompt them not to, and but few will need to, by reason of the positions open to them in industrial life. Under present regulations a large percentage of them will be too old to get permanent commissions after their temporary commissions are terminated. On the other hand, they are the men to whom is due a large share of present Coast Artillery efficiency, and the Coast Artillery cannot well afford to lose them. Wholly aside from any question of recognition for past services, a proper regard for future efficiency suggests the importance of providing a sufficient inducement to retain for the Corps the services of our former enlisted specialists after their temporary commissions are terminated.

Thus there seem to be two propositions worthy of the very serious consideration of all officers in the Corps. The first is the importance of building up a new body of enlisted specialists, who shall be carefully selected, worthy men, and surround them with a prestige which will allow a high professional standard and a positive esprit to be established and maintained. The second proposition, of no less importance, is the establishment of warrant grades. There are certain fields where specialization spells efficiency. This is notably true in the fields covered by the duties of Personnel Adjutants, Supply Officers, Orientation Officers, Communication Officers and assistants to Artillery Engineers. The establishment of warrant grades to provide for these positions would ensure that the highly specialized technique which each of them represents would be continuously cultivated by the men who would hold the responsibility for each position. It would further prevent the detailing of artillery officers away from their own particular functions. In the former specialists, now temporary officers, we have the competent personnel to fill these positions, and the establishment of these grades would provide a practical inducement for high-grade men to strive for appointment in the present enlisted specialist grades, through the door for further advancement that it would open to them. The Coast Artillery Corps has already made a good beginning in its warrant grades for the Mine Planter Service. It is but a step to extend this principle, but there is hardly a more important step that we could now take.

This suggestion for the establishment of warrant grades is postulated upon distinctly Coast Artillery needs, but it is presumable that all other arms of the service are confronted by comparable conditions for which the establishment of warrant grades would prove an equally desirable solution. Indeed, it is presumable that the subject is already under consideration. For this reason it is particularly desirable that the whole question should be thoroughly considered from the Coast Artillery standpoint so that when the occasion for definite action arises, the ideas of the Coast Artillery may be formulated to share in the general discussion and final decision of the whole question.

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TACTICS AND TECHNIQUE

In every arm of the service there is a bond between these two which is stronger than the tie of mere alliteration. Tactics and Technique are blood relations, and in every fighting arm tactics has been recognized as the elder brother. Invention and the improvement of matériel have progressively suggested changes in tactics, but it has always been the demands of the latest tactics which have controlled the modification of technique to handle new matériel, for the invention of a new weapon often suggests a new use for an old weapon.

Consequently, it is the business of tactics to maintain a scrutiny of the possibilities of all weapons, and to control the technique of their employment in order to assure the most useful employment of each. A very simple illustration of this principle may be seen in the employment of gas shells. Generally speaking, the persistent gases are much more powerful and deadly in their effects than the non-persistent gases. Considered from this standpoint alone, it would appear as an economy of artillery energy for the artillery to throw over nothing but persistent gases. But at this juncture tactics steps in and decides that at certain times, for instance just before an attack, the result that is desired from gas is neutralization rather than destruction, and further, that if gas is to be used, it must be used so as not to endanger our own infantry after it shall have advanced. Consequently, tactics intervenes to control artillery technique in this sort of a situation, by prescribing that the artillery shall use its energy in transporting to hostile territory a less deadly agent of destruction than the persistent gas which the artillery has at its disposal.

In the now remote days before the Great War, the Coast Artillery recognized the dominance of tactics over technique in its particular field, harbor defense. The effort was made to instil in the minds of all Coast Artillery officers the importance of tactical *conception*, and the correct processes of tactical *thinking* and *decision* to meet the distinctive problems of harbor defense. The tactical problems involved were so varied, the physical means to visualize and present them so difficult to attain, and the demands of our varied technique so engrossing, that the inculcation of sound tactical instruction has always been surrounded with difficulty. It may be said that substantial progress was being realized when along came the war and launched Coast Artillerymen into a diversion from the field of tactics with which they had previously been concerned. During the war, consideration of the distinctive tactics of harbor defense was subordinated to the demands of a new occasion, and the Coast Artillery was concerned with those applications of tactical principles which govern military operations in the field. During the course of their participation in these operations, those Coast Artillery officers of experience who had shared in the development of the tactics of harbor defense, were now forcibly impressed with the parallelism of the factors of dominating tactical significance to which the same heed must be given in field operations as in harbor defense operations. There were, of course, differences in the technical application of tactical principles, but the principles themselves were seen to be the same, and the factors controlling tactical action varied in form but not in kind, as for instance, the importance of concise and complete orders and messages; the interdependence of time, speed, and distance; the high value of defilade and concealment; the inherent relation between missions and methods of fire; and the ever-present question as to the accuracy of information.

As a result of this engrossing diversion of Coast Artillery activities, and the tremendous increase in personnel during this period, a large percentage of the younger officers of the Corps are approaching their share in the post-war rehabilitation of the harbor defenses with no background of experience in the characteristic application of tactical conception applicable to harbor defense problems. Fortunately they have been well grounded in fundamental tactical principles through their work with heavy artillery in land warfare. So the present need is simply that they be rightly led to apply these principles to the harbor defense problems now confronting them.

Again, all Coast Artillery officers, both old and young, henceforth must labor in a wider field than ever before. They must needs face not only the problems of local harbor defense, but as well, the more comprehensive problems of true coast defense and the service of the more powerful guns of army artillery, with all their corelative implications of extensive cooperation with every branch of the Army, and with the Navy.

In this greater task the mastery of technique will be insistently demanded. Nevertheless, for the Coast Artillery to play its part fully, this necessary regard for technical training must be coupled with a whole-hearted acceptance of the basic military law that *tactics rules technique.*

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DASH AND CLATTER

Once upon a time pensive traveller fared forth on a journey. Presently he entered a deep canyon between lofty mountains, and as he proceeded there smote upon his ears a deep and rumbling roar. This roar grew louder and louder as the traveller went down the valley, filling his soul with awe at the tumult thereof. Finally he came upon the cause of his wonderment. Before his eyes a great cataract tumbled its hurrying flood over a dreadful cliff, the torrent hurling itself on the rough rocks beneath in a mad diapason of reverberating thunder, and filling the abyss below him with a radiant mist, scintillating in the brilliant sunlight. Deeply impressed in spirit and pondering the wonder of what he saw, the traveller skirted the waterfall and picked his careful way down the now treacherous trail through the canyon. When he had neared the bottom he encountered a man standing by a small but massive structure of stone. He greeted the stranger and thus gave expression to the solemn impression made by the titanic sight he had passed: "My friend, I am overcome with awe at the loud and awful expression of divine energy voiced by this cararact above us." Whereat the stranger led him to the low stone building, and pointing to a silent and mighty flow issuing from the tailstock of a turbine, quoth aloud: "Sir, the noisy torrent above is but a waste of water which cannot be used. Your awe would be more truly conceived in the contemplation of this noiseless stream, which in its uncomplaining passage is giving its energy in light, heat, and power to the peoples of two great cities out yonder on the plain."

Through the ages the parable has been a vehicle of paternal counsel. A new generation of Coast Artillery officers is now among us. Their outlook on the service has been colored by the tumult of the great emergency which called them to the colors. For those who are to stay in the Coast Artillery as a profession a new outlook is necessary. To these then is addressed the lesson of this simple parable. During the war the duties of many officers associated them with expressions of military activity connoted with a certain dash and clatter—hurried movements, by ship and by rail, the beating of hoofs, the rattle of wheels, the roar of motors, often overlaid with a staccato accompaniment of the treble of rifle and machine gun fire, and the bass obbligato of the artillery. With the war over, much of the "dash" is gone, in the work of all arms of the service—not to recur in such hectic intensity until the time of another war. This does not mean that with the noise gone, the work we are to do will be inefficient or unimportant.

Remember that the loud rattling of gears in a machine more often means that the gears do not mesh properly and that power is being wasted, than that the machine is operating at a high state of efficiency.

In the Coast Artillery perhaps it is particularly true that much of the soundest accomplishment of the next years will be attained without assailing either the eye or ear. The young Coast Artilleryman should be stimulated by the realization that a very wide field for development which has not yet been thoroughly mapped has still been clearly visioned, and the field is open for him to till, even now in the interregnum of policy that must needs prevail until Congressional enactment shall have again set the boundaries of military policy. The spirit of youth is more impressed by the sight of a hundred yard dash than by the determined endurance of a marathon, but in the Coast Artillery professional recognition is the fruit of long diligence and application rather than the meed of spectacular deeds of prowess. The road to success lies through mental alertness and physical activity, and from the assurance of his comrades longer in the service the youngster may feel confident that in the long run *the game is worth the candle.*

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PROGRESS IN BALLISTICS

The JOURNAL desires to invite particular attention to the article appearing in this issue entitled "The Numerical Integration of Differential Equations," by Major F. R. Moulton, Ordnance Department. This article is the first of a logical and considerable series of technical articles prepared by officers of the Ordnance Department and Coast Artillery, covering a wide field in the progress in the science of ballistics and gunnery during the war. The articles at present available have been written by ten different officers, but are mutually related and for the most part employ the same symbols and terminology. It may not be generally known to readers of the JOURNAL that during the war some of the most eminent mathematicians and physicists of the country gave their services as officers of Ordnance, and the fruit of their collaboration with officers of the regular service represents the most signal advance in ballistics in twenty or more years. With the war at an end, nearly all of these gentlemen have discarded martial garb and have returned to university chairs and other civil pursuits, so that it is highly desirable that their war-time work be collated and crystalized in print, lest it be lost for the future benefit of the artillery. Hence this series of articles.

The editors of the JOURNAL confess that the contents of some of these articles appear rather formidable to them, and perhaps will appear the same way to some of the readers of the JOURNAL, but at the same time it is realized that there are readers who will distincly relish these contributions which are decidedly out of the popular fiction class. Seriously, however, it is believed that these articles will break the ground for a more general delving of the ballistic field by Coast Artillery officers, and the JOURNAL suggests that, based on the thorough analytical discussion of this series, there is a demand for a comprehensive presentation of up-to-date ideas on ballistics and gunnery, set forth in simple form and pitched to a mathematical key such that the average artillery officer can carry the theme and keep in tune. There are certainly a few Coast Artillery officers with the mathematical trend and training to seize upon the recent developments in the ballistic field, and to carry forward the investigations necessary to the final determination of ballistic problems. It is neither possible nor necessary that every Coast Artillery officer should be an expert ballistician. Nevertheless, every Coast Artillery officer should be a master of gunnery, and to interpret all the conditions that will confront him in various gunnery problems, he must be familiar with ballistic principles, although he need not know involved ballistic processes. So, for the use of the great majority of Coast Artillery officers who are to be gunners and not ballisticians, there is this demand, as already noted, for a simple presentation of recent developments in ballistics. Happily, the JOURNAL is able to inform this large class of readers that all of this new data is being digested by certain officers who will undertake to assemble the gist of it in simple form, stripped of deep mathematical exposition, for publication in the JOURNAL. Meanwhile, the co-operation of any other officers along the same line is earnestly suggested.

In focussing our attention on the recent noteworthy progress in ballistics, it is apropos to remember that the groundwork for American ballistic practice was laid by Artillery officers, notably Ingalls and Hamilton. Their contributions to the science of ballistics and gunnery have established conceptions which are accepted abroad as well as in America. Their work was achieved in the face of a discouraging paucity of means for experiment and practical research. Yet they and numerous Coast Artillery officers in recent years, carrying forward their work, had gone far toward establishing ballistics and gunnery as an exact science. There is still much to be done to divorce ballistics from the realm of the empirical. Major Moulton and his colleagues have opened several new doors. The Coast Artillery has now the province and the opportunity to enter those doors and possess the fields which lie beyond.

PROFESSIONAL NOTES

A Study of the Armament, Calibers, and Types of Matériel, Kinds and Proportion of Ammunition, and Methods of Transport of the Artillery to be Assigned to a Field Army

Report of Board of Officers Appointed by Par. 142. Special Orders No. 289-0, War Department, 1918.

APPROVED,
By Order of the Secretary of War:
P. C. MARCH,
General, Chief of Staff.

The Minority report is noted and need not delay the approval of the report proper.

MARCH,
C. of S.

May 23, 1919.

1. Report of a Board of Officers convened pursuant to the following order:

WAR DEPARTMENT,
Washington, December 11, 1918.

Special Orders)
No. 289-0)

Extract

CONFIDENTIAL.

Par. 142. A board of officers to consist of:

Brigadier General William I. Westervelt, U. S. Army.
Brigadier General Robert E. Callan, U. S. Army.
Brigadier General William P. Ennis, U. S. Army.
Colonel James B. Dillard, U. S. Army.
Colonel Ralph McT. Pennell, U. S. Army.
Lieutenant Colonel Webster A. Capron, U. S. Army.
Lieutenant Colonel Walter P. Boatwright, U. S. Army.

is appointed to meet at A.P.O. 706, France, at the earliest practicable date, to make a study of the armament, calibers and types of matériel, kinds and proportion of ammunition, and methods of transport of the artillery to be assigned to a Field Army.

During the time that the board is in session abroad, it will be under the direction of the Commander-in-Chief, A.E.F., France, who will issue the necessary travel orders.

After completing its investigations abroad, the board will return to the United States to finish its work at such ordnance and other plants in the Unites States as may be necessary.

334.2 (Field Artillery Equipment).

The travel directed is necessary in the military service.

By order of the Secretary of War:

PEYTON C. MARCH,
General, Chief of Staff.

OFFICIAL:
P. C. HARRIS,
The Adjutant General.

Washington, D. C., May 5, 1919.

The Board met January 12, 1919, at Chaumont, France, and, after organization, arranged for the accumulation of such artillery data as were available in France, visited manufacturing plants, and had conferences with the French and American artillery officers. It visited Italy, had conferences with the higher technical and artillery officers, visited manufacturing plants and had a conference on types and tactical uses of artillery at the Italian Great Headquarters. Similar opportunities were afforded the Board by the British at their Great Headquarters in France and at their War Ministry in England.

2. In making up its report, the Board has adopted the following general scheme of discussing and developing the subject:

I. The artillery of a field army; its functions (Par. 3-5 incl.)
  (a) Division artillery missions (Par. 6 - 9).
  (b) Corps artillery mission (Par. 10).
  (c) Army artillery missions (Par. 11 - 13).
II. Discussion of types of artillery.
  (a) Light field gun (Par. 14).
  (b) Light field howitzer (Par. 15).
  (c) Medium field gun (Par. 16).
  (d) Medium field howitzer (Par. 17).
  (e) Heavy field gun (Par. 18).
  (f) Heavy field howitzer (Par. 19).
  (g) Super guns and howitzers (Par. 20).
III. Improvement in design and construction of projectiles (Par. 21 - 28).
IV. Types of artillery recommended: ideal and practical.
  Light field artillery.
    (a) Gun (Par. 29 - 32).
    (b) Howitzer (Par. 33 - 35).
  Medium field artillery.
    (c) Gun (Par. 36 - 38).
    (d) Howitzer (Par. 39 - 40).
  Heavy field artillery.
    (e) Gun (Par. 41 - 43).
    (f) Howitzer (Par. 44 - 46).
  Weapons of greater power.
    (g) Heavy gun (Par. 47).

(h) Heavy howitzer (Par. 48 - 50).
(i) Super guns (Par. 51 - 56).
(j) Super howitzers (Par. 57 - 62).
Other artillery.
(k) Anti-aircraft; light gun, heavy gun (Par. 63 - 69).
(l) Pack artillery (Par. 70 - 71).
(m) Infantry accompanying gun (Par. 72 - 74).
(n) Trench artillery (Par. 75).
(o) Anti-tank gun (Par. 76).
V. Artillery transport.
General discussion (Par. 77 - 84).
Gasoline propelled vehicles (Par. 85).
Motor cars (Par. 86).
Motor trucks (Par. 87 - 89).
Caterpillars (Par. 90).
History of artillery motorization in the United States (Par. 91 - 97).
Types produced by the Ordnance Department (Par. 98).
Types recommended to be developed (Par. 99 - 101).
Tractors (Par. 102 - 103).
Trucks (Par. 104).
Trailers (Par. 105).
Tractor caissons (Par. 106).
Self-propelled gun mounts (Par. 107 - 110).
Complete plan of artillery motorization (Par. 111 - 112).
Immediate application of the above plan (Par. 113).
Special recommendations (Par. 114).

I. THE ARTILLERY OF A FIELD ARMY: ITS FUNCTIONS

3. The artillery assigned to a Field Army should be of such mobility, power, variety and number as to insure the success of the mission involved and to enable this success to be gained with the minimum of casualties. The latter point must receive careful consideration in studies of organization, for without adequate artillery preparation and support the successes of the most gallant infantry can, in a series of actions, become little more than pyrrhic victories. While it is not within the province of this board to discuss this question, it may be well not to leave it without stating that many actions of our divisions in France resulted in casualties whose numbers were a decreasing function of the number of guns with which divisions were supported. The proportion of guns per thousand gross strength to infantry, cavalry, and machine guns adopted by the armies of the first-class powers before the opening of the present European War in 1914 was:

British	6.8	
French	4.6	
German	6.4	
American	3.2	(Greble Board)

During the war this proportion was constantly increased until at the close under conditions of position warfare it was between 8 and 12 per thousand; this varied, of course, with the activity in different sectors. In quiet sectors and under conditions of maneuver warfare which necessitated leaving much artillery behind it was about 6 per thousand.

4. A study of the types of artillery actually employed by the field

armies in Europe might lead to some errors in drawing conclusions as to what should constitute a proper armament, for the reason that the various countries involved had to use existing types which they had at the beginning of the war, whether satisfactory or not, and build new and supplementary types, not always the ideal, even from their own standpoint, but such as the manufacturing facilities of their countries permitted. The development of types due to the emergency and the use of antiquated matériel multiplied the types for which ammunition had to be supplied; the war in turn also multiplied the types of ammunition which had to be supplied to a particular type of artillery. Such a condition of artillery matériel could only produce a limited degree of artillery efficiency, a mass of types of questionable value and great expenditure of money and industrial effort.

5. An artillery program should be founded on the object and the means —that is, the destruction of the target and the projectile to accomplish this. It should also admit of a proper series of ranges that would fulfill all the tactical requirements that could reasonably be expected of a series of types. In the study of an artillery program there are two methods of approaching the subject. First, by starting with a minimum weight of projectile and working up to a reasonable maximum according to some law and taking the corresponding calibers, a theoretical series of guns and howitzers can be expressed. For instance, if the law be doubling the weight of projectile the series could be:

Projectile	of	13	lbs.,	caliber	3″
“	“	26	“	“	4″
“	“	52	“	“	5″
“	“	104	“	“	6″
“	“	208	“	“	8″
“	“	416	“	“	10″
“	“	832	“	“	12″
“	“	1664	“	“	14″

The second and more logical method, and the one followed by the board, is to consider the artillery missions and determine the types best suited irrespective of any theoretical series. However, in the discussions of artillery missions and the proper types for their fulfilment which the board had with our own and foreign officers, there was a remarkable degree of unanimity of thought on these subjects; and the above table actually contains, with slight variations, the types that were most strongly recommended. While granting the great variety of artillery missions that often shade into each other, it is believed that they can best be considered in three great classes that follow the tactical composition of a field army; those of division, corps, and army artillery.

(a) Division Artillery Missions

6. The division artillery, first of all, must have the mobility that will permit it to accompany the infantry of a division and the maximum power consistent with this mobility; its objective must be primarily the infantry of the opposing division. It is, therefore, bound to its own infantry with the closest bonds and its tactical use cannot be separated from that of the infantry. The division artillery must fire accurately a man-killing projectile and be prepared for quick changes of objective; it must have great range

because of echelonment in depth, both of its own and the opposing division; it must continually harass the enemy, prevent his movement and force him into cover or protected trenches. On the defensive it must break up the opposing infantry formations by counter-offensive preparation and by annihilating fire on points from which the attacks emerge; and, failing in these, be prepared to use the barrage and the close range shrapnel fire. In the offensive the division artillery must play its part in the complex scheme of artillery preparation by cutting wire, destroying machine gun nests, gassing areas, concentrating on infantry positions and taking the principal part in the deep barrage that should precede the infantry attack. Its fire, accompanying the infantry movement, requires its own movement by echelons; and by its mobility it often becomes for some time the sole artillery protection in the consolidation of a position which has been taken.

7. It would be ideal if one type of weapon could accomplish all the requirements that the division artillery should fulfill, and some artillery officers in one of the foreign armies have made a study of a gun-howitzer with this in mind. The objections to such a gun-howitzer are:

(a) That it would require the use of a projectile of about 30 lbs., which is about twice that of the normal field gun ammunition, thereby greatly increasing the tonnage of ammunition supply for the same volume of fire.

(b) That it would require a complication of the ammunition supply to individual batteries in that both fixed and semi-fixed ammunition would have to be supplied if the double function of the piece was to be taken advantage of at any time. To meet this by having all the ammunition semi-fixed would result in a decreased rate of fire when the piece was used as a gun.

(c) That to obtain fairly good gun characteristics the weight of the piece and carriage would be increased and, therefore, the mobility decreased.

(d) That in any case the piece would not be the best type of either field gun or field howitzer.

8. The consensus of opinion of artillery officers is that the division artillery missions are best fulfilled by a light field gun and a light field howitzer having a range of at least 11,000 yards. While differing in mechanical features the field guns of the different European countries are practically of the same type and, though constant effort is being made to improve details, they can be stated generally as satisfactory to their own governments and not liable to any radical changes. This general type of field gun, while capable of fulfilling most of the division artillery missions, must be supplemented by a proper howitzer. There are many instances where the terrain offers such protection to infantry that the field gun cannot bring an effective fire. The howitzer has the great advantage that with a proper set of propelling charges and, therefore, a choice of trajectories for the same range, protected positions can be chosen for howitzers that guns could not use, and angles of fall on objectives obtained that the normal ammunition of guns would not give. The low muzzle velocity of howitzers admits of their almost continuous use in harassing fire and allows the use of a projectile double the weight of that of the field gun. Such a howitzer renders excellent service in wire cutting and is a useful projector of gas shells. To insure the mobility required of all divisional artillery the weight of the howitzer and carriage should not exceed that of the field gun and carriage, or about 4500 lbs.

9. In connection with the support of the division infantry by the division artillery the war has intensified the old question of accompanying guns for infantry. A solution of this question by the assignment of batteries of field artillery has been tried but the general opinion is that the field artillery gun is not satisfactory for this purpose; it is too vulnerable a target in motion; the ammunition supply is difficult; it is not sufficiently mobile because it cannot be man-handled; and from the division artillery standpoint the loss of the control of these batteries breaks down the power of the division artillery. One of the most serious obstacles to the advance of infantry is the enemy's machine guns. If the machine gun nest is isolated it is relatively simple to maneuver in such a way as to neutralize it. If, however, there is a line of machine gun nests it becomes necessary to destroy a certain number in order to out maneuver the others. The infantry rifles, machine guns, and 37 mm. guns are not sufficient for the latter mission. It is not always easy to obtain promptly the action of the division artillery, usually some distance in the rear, and it is difficult to indicate to the artillery the exact location of the machine gun nests. For the above reasons it seems proper that a special gun, designed for the destruction of machine gun nests and other light forms of enemy resistance, should be provided. This gun should have such mobility that it can be man-handled as a unit, that is, dragged along on a low wheeled mount; it should be accurate for its purpose up to 2500 yards and use a large capacity high explosive shell. Its carriage should also admit of ready adaption for use in trenches.

(b) Corps Artillery Missions

10. It will be noted above that the division artillery missions did not include their own protection against enemy artillery. This counter-battery work is the principal mission of the corps artillery. There are American officers who advance the idea that, because of their actual experience in not receiving proper corps artillery support, the division should be supplied with counter-battery artillery; the matter is complicated because the 155 mm. howitzer which formed part of our division artillery brigades is an ideal counter-battery weapon, and further by the fact that these howitzers did not form a part of our corps artillery, which organically consisted of guns alone. This should not divert us from the fact that the mission of counter-battering the enemy's gun belongs to the corps which has the proper agencies for determining the position of enemy guns and for co-ordinating this work so as to fit in with the plans of the corps commander. The corps artillery has also the missions of extensive harassing and interdicting fire along the corps front and to a greater depth than the capabilities of the division artillery; also of destructive fire on strong points as well as on railroad facilities and points of supply. For the accomplishment of these corps artillery missions there are two distinct types of artillery necessary, a gun and a howitzer, each having about 16,000 yards range and each weighing with carriage about 11,000 lbs.

There is another class of artillery called anti-aircraft artillery to be considered. This is used first in providing anti-aircraft defense to troops engaged in combat and, second, in providing anti-aircraft defense for army zones, for certain areas in rear of armies or along certain line of anti-aircraft defense.

The first class gives protection from low flying air-planes to troops engaged in combat; it should, therefore, form part of the field army. The second class is part of the general anti-aircraft defense and works in co-ordination with the air service, balloon defense, searchlights, and anti-aircraft machine guns, thus forming the anti-aircraft defense service.

(c) Army Artillery Missions

11. In addition to the division and corps artillery fulfilling the missions outlined above there must be additional artillery available; there are missions of interdiction, neutralization, and destruction which fall beyond the activities or capabilities of the normal corps or medium field types; there must exist a surplus of divisions or corps types, properly transported, for strategic reinforcement of divisions and corps during such times as the normal allotment to such units is insufficient; there must be artillery of special purpose—pack artillery, trench artillery, and super-guns and howitzers.

Of the above additional artillery, a type of heavy field gun and a type of heavy field howitzer are considered normally necessary in the armament of a field army; the gun should have a range of approximately 25,000 yards, and the howitzer a range of about 18,000 yards. These weapons, more powerful than the medium field types, add range to the interdiction and harassing, and to the neutralization and destruction possible with the corps types.

12. Considering paragraphs 3 - 11 inclusive it will be seen that the normal artillery missions of a field army can be accomplished by an assignment of six calibers, i.e., two light weapons, two medium weapons and two heavy weapons,—a gun and a howitzer in each class—and a satisfactory anti-aircraft gun.

13. The surplus of field army types for strategic reinforcement of their respective units, the artillery of special purpose,—pack artillery, trench artillery, obsolescent types, and super-guns and howitzers,—are believed to be outside of the normal assignment of armament to a Field Army. At times all or any of the special types are necessary in field army missions; these types have no continuing purpose and should, therefore, be looked upon and organized as available reinforcement or reserve for the artillery of field armies.

II. DISCUSSION OF TYPES OF ARTILLERY

(a) The Light Field Gun

14. The consensus of opinion of all artillery officers—French, Italian, English, and American—is that the 75 mm. gun, or approximately this caliber, firing a 15-pound projectile or a projectile of approximately this weight, and having a range of not less than 11,000 yards, is a satisfactory weapon at the present time for use with division artillery. The projectile in question, whether a shrapnel or high explosive shell, satisfies adequately the criterion of man-killing.

At the close of the war the nations were not entirely in accord with respect to their conception of an up-to-date carriage for the light field gun. All the nations whose tendencies have been considered in this report have experimented to a varying degree with field gun carriages, particularly in a desire to design a carriage permitting a greater angle of elevation and a greater movement of the gun in traverse. The Italians have expressed themselves in the modified Deport carriage; this vehicle is of the split-trail type and permits an elevation in excess of 75 degrees, and a traverse on each side of the carriage axis of about 20 degrees. The High Command informed the board that this carriage had given such excellent service that no consideration had been given to the design of a different type carriage.

Up to the time that the board left France it was not possible to learn the French decision in the matter of a split-trail carriage for their light field gun. It is known, however, that several types of this carriage have been designed and tested; it is known, also, that considerable favor has been found with the American 1916, which type has been tested under the auspices of the French Government. In England, however, the board was not able to develop any enthusiasm for the split-trail type, although the matter had been seriously considered. In that country the up-to-date field gun carriage appears to be adequately expressed in their new 18-pdr. The vehicle upon which this gun is mounted permits an elevation of 37 degrees and an axle traverse of 4½ degrees on each side. The trail is a box trail and the carriage is simple and steady in its construction and lends itself to rapid production. The Vickers Company have designed and manufactured one split-trail carriage, presumably with a view of having the details of such carriage in hand in the event of a service demand for such vehicle.

The split-trail carriage is fairly well known in the United States; opinion has not yet been crystallized throughout the artillery, which is still more or less open-minded and quite willing to accept the tactical advantages of the split-trail type when some of the present mechanical disadvantages shall have been remedied. It may be stated that the field artillery would be glad to have a possibility of increased elevation and increased traverse, provided the simplicity of construction inherent in the single trail type can be retained. The field artillery believes that a satisfactory split-trail type of carriage can be made.

It is desirable that the breech blocks of all weapons be confined to one type. The three types of breech blocks in use in the present American 75 mm. guns are the French rotating block, the American drop wedge block and the British swinging block. All three types are in general satisfactory. The firing mechanism should be of the fewest possible number of working parts preferably of the lanyard type.

The consensus of opinion was that the independent line of sight is necessary; also that the general type of panoramic sight of American design with graduations from zero to 6400 mils in azimuth is preferable.

At some time in the future it is probable that all division artillery will be motorized. The result of such change in the prime mover would be to remove the present restriction as to weight of gun and carriage. The board senses a demand in the near future for a light field gun having a maximum range of approximately 15,000 yards; such range may be achieved by inincreasing the muzzle velocity and, perhaps, the weight of the projectile, although change in the form of projectiles will give some improvement over the present ranges. It is probable that the limiting feature in the design of field guns of the future will be the requirement that it should pass safely over temporary pontoon bridges and that the weight and form and size of ammunition must be such that the present rate of fire will not be slowed down.

The board is of the opinion that, except as to perfection of details, the limit of carriage design, as expressed by the most modern type of box trail and split-trail carriages, has been reached; and feels that with the advent of motor transportation the tendency will be toward a gun mount of the pedestal type expressing the desires of the field artillery with respect to maximum horizontal and vertical arcs of fire.

(b) *The Light Field Howitzer*

15. The consensus of opinion of American artillery officers consulted is that a howitzer of about 4 inches in caliber, firing a projectile weighing from 25 to 30 pounds at a maximum range greater than 10,000 yards, is required. This opinion is concurred in by the French, Italians, and English, and it appears further to be definitely established that the mobility of the light field howitzer should be practically the same as that of the light field gun.

The British Army was equipped with a 4½-inch howitzer, firing a projectile weighing 35 pounds and with a maximum range of 7700 yards; the weight of the howitzer limbered is 4676 pounds,—150 pounds more than the weight of the 18-pdr. field gun—no evidence was found that the British government intended making any alterations in the design of this howitzer; naturally, they will attempt to increase the range, power and accuracy of the projectile by change in its weight, its capacity and its co-efficient of form. During the war the proportion of 4½-inch howitzers to 3.3-inch field guns was 33-1/3 per cent; 25,000,000 rounds were fired from the 4½-inch howitzers as compared with 100,000,000 rounds fired from the 3.3-inch field guns.

The French artillery was not equipped with the light field howitzer of approximately the same weight as the 75 mm. field gun. There is some difference of opinion among officers of the French artillery as to the necessity for a light field howitzer, though it is believed the best opinion favors the adoption of such type. During the war it was found impracticable to construct a light howitzer without interfering with the production of other calibers which were considered more important.

In the earlier stages of the war the Italian artillery was not equipped with a light field howitzer; however, before the end of 1917 orders were placed for several hundred 105 mm. howitzers. The Italian General Staff is not prepared to state that a light field howitzer is altogether a necessary part of the artillery equipment of a field army. The opinion, however, of artillery officers on this subject is divided. It should be noted that several hundred howitzers of this caliber were being constructed before the armistice and that many have been captured from the Austrians by the Italians; this, so far as the Italians are concerned, makes it certain that a light field howitzer will be furnished the Italian Army.

The German and Austrian armies were equipped with a howitzer of the light field type; this weapon had a caliber of 105 mm., firing a projectile weighing 34.54 pounds at a maximum range of 10,500 yds. (stream line shell). The weight of the howitzer limbered was 4500 pounds.

In the opinion of the board, the Germans have proceeded on sound principles in their development of the light field howitzer. Their '98 model was a companion piece for their '96 field gun and in the years that passed from 1898 until 1916 which included their early war experience they kept to the idea of the relation of the two pieces even to the extent of including in a field artillery regiment one battalion of the light howitzers. Their 1916 models of both light gun and howitzer show the endeavor to keep the pieces in the same class; that is, the weight of gun and howitzer in action nearly the same, 2750 lbs. and 2700 lbs.; the weight of the gun limbered and howitzer limbered the same, 4500 lbs.; the elevation of both the same,—minus 10 to plus 40 degrees; the carriages are the same type; and the extreme ranges of gun and howitzer are respectively 11,700 yards and 10,500 yards.

From the above it is seen that all the important belligerents except the French and the Americans were equipped with a light field howitzer firing a projectile about twice the weight of the light field gun projectile and having otherwise the same general characteristics. There is no evidence to show that the fire of the French and American artillery was not fully as effective as that of any other artillery; however, the testimony of the French and American artillery officers is to the effect:

(a) That the lightest howitzer in use, i.e., the 155 mm. gun, was not sufficiently mobile to be a suitable companion piece for the 75 mm. gun.

(b) That many times the fire of the 75 mm. gun proved ineffective due to its flat trajectory; a howitzer would have been more effective in the attack of certain targets.

(c) That a large volume of fire is necessary.

(d) That while the 155 mm. howitzer is more powerful than the lighter field howitzer, its consumption of ammunition for many purposes is wasteful and extravagent and its volume of fire is insufficient.

(e) That the light howitzer is particularly suited for the destruction of wire entanglements; its better accuracy and more powerful projectile make it more suitable than the field gun for this purpose.

(f) That the 75 mm. field gun projectile is not so satisfactory a gas vehicle as the howitzer projectile which has greater weight.

(c) *The Medium Field Gun*

16. The consensus of opinion of artillery officers,—Italian, English, and American,—is that a medium caliber field gun, i.e., a caliber between the light field gun and the field gun of about 6-inch caliber is necessary. The French are not entirely convinced of this necessity and hold divided opinion. The Chief of the French Artillery Mission attached to the Chief of Artillery, American E.F., is strongly of the opinion that a medium caliber field gun should be interpolated.

The medium type gun furnished to the American army was the 4.7-inch (Model 1906). This gun has a maximum elevation of 15 degrees, with a corresponding maximum range of 8700 yards.

The British army was equipped with the 5-inch gun,—the carriage permits a maximum elevation of 21 degrees 30 minutes, giving a maximum range of 12,500 yards.

The French army was equipped, to a certain extent, with the 105 mm. and the 140 mm. gun. The 105 mm. gun has a maximum elevation of 37 degrees, with a maximum range of 13,900 yards. The 140 mm. gun has a maximum elevation of 30 degrees, and, with a high velocity, has a maximum range of 19,500 yards. The French 105 mm. gun is a modern weapon (1913).

The German artillery was equipped with a 105 mm. gun, (Model 1917) with a maximum elevation of 45 degrees, and a maximum range of 16,000 yards. The German artillery was also equipped with the 130 mm. gun, having a maximum range of 16,500 yards. The Austrian artillery was similarly equipped.

The Italians were equipped with a 105 mm. gun essentially of the same characteristics as the French 105 mm. ,Model 1913.

(d) *The Medium Field Howitzer*

17. In the opinion of the French, the Italians, the British, and the Americans, the 155 mm. howitzer (Schneider) was conspicuously successful in the present war. It should, therefore, be retained as a type.

The howitzer and carriage, as it stands at present, is a highly satisfactory and efficient piece of armament. For the future it is believed that effort should be made to increase the range by improvements in the form of projectile, and it is believed that the form of howitzer and carriage should be studied with a view of obtaining, through modifications, a maximum range of approximately 16,000 yards.

Many batteries of 155 mm. howitzers (Schneider) were motorized in the American army in France, and the consensus of opinion is definitely toward the retention of this form of prime-mover.

It is interesting to note that all of the important belligerents have settled upon a howitzer of approximately 6-inch in caliber, and otherwise essentially of the same ballistic characteristics as the type in question.

The projectile of this caliber is the smallest projectile which can be called upon to give adequate mining effect against material targets of simipermanent nature. The place of this howitzer is, therefore, determined by considerations of its destructive ability. It is a splendid destruction and neutralizing weapon.

(e) *The Heavy Field Gun*

18. The consensus of opinion of all artillery officers—English, Italian, and American,—is that the heavy field gun should be of approximately 6-inch caliber, and that guns greater than this are necessary in limited numbers for field operations. The French were constructing 194 mm. guns during the latter stages of the war. It is believed that in developing this type of gun the French were actuated almost entirely by the necessity for increased range, since the German 150 mm. gun, Model 1916, outranged the G. P. F. by approximately 5,500 yards. The French have recently made considerable progress in securing the necessary increase in range with the G.P.F. The latest British 6-inch gun gives a maximum range with a 100 lb. projectile of 23,000 yards at 38 degrees elevation, the carriage permitting 8 degrees traverse.

All of the principal nations engaged in the war used a heavy field gun of approximately 6-inch caliber. This type has given such general satisfaction that its continuance is assured. The principal missions of the heavy field gun are harassing and interdiction fire, and for these uses the 6-inch projectile is sufficiently heavy.

The maximum practicable traverse and elevation should be provided by the carriage for the heavy field gun. The G.P.F. carriage has given general satisfaction, but its wide tread and the excessive time required to occupy a position are very objectionable features.

It is the consensus of opinion of all artillery officers,—French, British, and American,—that the heavy field gun should be of approximately 6-inch caliber with a range in excess of 25,000 yds., with not less than 60 degrees traverse, weighing not more than 12 tons limbered, capable of occupying and leaving a position quickly, and with a width of tread which does not prevent 2-way traffic in ordinary roads. The Italians differ from this opinion only in that they are satisfied with a maximum range of 18,000 yards.

(f) *The Heavy Field Howitzer.*

19. No type of heavy field howitzer developed during the war has given general satisfaction. The consensus of opinion of all artillery officers,—French, British, and American,—is that two calibers of field howitzers are necessary, one a companion piece for the 6-inch gun and one of the maximum possible power consistent with the necessary mobility. The lighter of these two howitzers should have the same mobility as the 6-inch gun, with a caliber of about 8-inch and a maximum range of not less than 16,000 yds. The heavier field howitzer should be of about 9.5 inches caliber with a range in excess of 16,000 yds.; the carriage should provide for wide traverse and must have sufficient mobility to accompany an army in the field. It will probably be necessary to transport this howitzer in more than one load, and the maximum weight of any load should not exceed 12 tons. The average time necessary for occupying a position should not exceed six hours under actual field conditions.

(g) *Super-heavy Guns and Howitzers.*

20. The war has demonstrated the necessity for long range and powerful guns for distant interdiction and harassing work and for super-heavy howitzers for the destruction of semi-permanent fortifications. Artillery of these types can best be mounted on railway carriages and this type of mount offers no serious disadvantages since these guns will not be used except with large forces which require extensive railroad systems for their supply. This does not apply to guns of the type used to bombard Paris; such guns have no military value and their construction is not justifiable.

The British have got satisfactory results from their 9.2-inch gun and their 12-inch howitzer and their 14-inch gun on the Armstrong mount. The French have used a large variety of guns on railroad mounts and during the last year of the war were constructing a considerable number of very long range weapons. While admitting that we may never be engaged in another war in which operations assume exactly the form which for so long existed on the Western front, it is the consensus of opinion of artillery officers-American, French, and English,-that railroad artillery is a necessity in operations that will invariably result when large forces are engaged. These types are needed in limited quantities, considering the needs of Field Armies only, and should be of four calibers: an 8-inch with all round fire, a maximum range of 35,000 yards and capable of being transported on a narrow gauge track; a 14-inch gun with a range of 40,000 yards and limited traverse; a howitzer of about 12-inch caliber, with a range of not less than 25,000 yards and a 360 degree traverse, and a 16-inch howitzer having a maximum range of not less than 27,000 yards and with limited traverse. Of these types the 8-inch should predominate in number.

These types will not only be needed in field operations but also in the initial contact with the enemy at the coast line and boundaries. The latter use should determine the exact characteristics and numbers of these guns and howitzers and the numbers to be assigned to the general artillery reserve will depend on the general military situation as viewed by the High Command.

III. IMPROVEMENTS IN DESIGN AND CONSTRUCTION OF PROJECTILES

21. Great thought has been devoted to this subject during the war and many experiments have been made. It may be stated that the general laws governing the design of projectles for maximum ballistic efficiency have not been formulated and, in fact, there is at the present time insufficient data upon which to proceed. The false ogive, boat-tailing, alterations in the shape and location of rotating bands have greatly increased the range of modern projectiles, but there are critical points in each of these modifications at which improvement ceases. There are investigations under way by the Ordnance Department covering this entire subject and the Board recommends that these be continued. It is to be expected that this subject will require extended investigation and is one which can only be adequately handled by a continuing technical body.

22. The development of the mechanical time fuse should be actively prosecuted. This fuse is particularly valuable for high altitude trajectories, but the powder train fuse as now manufactured must be continued for bulk production on account of the almost negligible manufacturing capacity existing or likely to exist for the mechanical fuse.

23. The Board desires to emphasize the necessity for making fuses for high explosive shell bore-safe. The French type super-quick fuse is seriously defective in this regard. The destruction of cannon due to premature bursts during the past war has been enormous, due largely, in the opinion of the Board, to the use of this fuse.

24. It is especially desirable to reduce the types of fuses issued to any single organization. In the past war the 75 mm. shells were normally supplied with four varieties of fuse ranging from the super-quick to the long delay. The evidence before the Board is to the effect that this is an unnecessary complication, and it is recommended that the number be reduced to two. A similar policy has been followed in all other calibers.

25. It has been considered fundamental that all guns be furnished with a type of projectile which will give the maximum range, and that all howitzers except the 105. mm be furnished with a type of shell to carry the maximum bursting charge. It has also been considered that semi-steel (cast iron) projectiles should be supplied for production reasons in the most important calibers requiring enormous quantity production. It is considered that the semi-steel projectiles have proved efficient against animate targets and are reasonably satisfactory against matériel where burst above the ground is desired.

26. In connection with fuses, by "super-quick" the Board means a fuse which will burst the projectile above the ground without any crater whatever. By "instantaneous" is meant a fuse which will burst the projectile on the outside of a hard surface such as a concrete emplacement before penetration or ricochet. This fuse will give some crater on hard ground. By "short delay" is meant a fuse which will burst the projectile on ricochet, preferably at a height of about 6 to 10 feet. Some crater effect will be obtained on hard ground but the fuse is desired for ricochet effect. By "long delay" is meant a fuse which will burst the projectile after complete penetration into hard ground. Obviously there will be a variation in the time element in long delay fuses required for such different types as a 155 mm. Howitzer projectile and a 16-inch Howitzer projectile in order to obtain in each case the maximum

mining effect. This is a question to be determined by the Ordnance Department.

27. The Board has purposely used the term "super-charge" in referring to the propelling charge required in the case of guns to give the maximum ranges. It cannot be too strongly emphasized that the normal charge should be used always within the maximum ranges obtainable with it and the use of super-charges must be prohibited except where necessary, otherwise the wear on the guns will become inadmissible.

28. The Board desires to point out the defects in nitrocellulose powder. This powder takes up moisture from a damp atmosphere and deteriorates in its ballistic qualities. It requires elaborate and expensive containers and, even with the containers which have been provided, large quantities of powder have been rendered unfit for service. A powder containing nitro glycerine or similar compounds can be used in simpler containers and will tolerate adverse conditions of moisture

IV. Types of Artillery Recommended; Ideal and Practical

Light Field Artillery

29. (a) Gun. Ideal. A gun of about 3-inch caliber on a carriage permitting a vertical arc fire of from minus 5 degrees to plus 80 degrees, and a horizontal arc of fire of 360 degrees; a projectile weighing not over 20 pounds, shrapnel and high explosive shell of satisfactory man-killing characteristics with maximum range of 15,000 yards; fixed ammunition; smokeless, flashless propelling charge; time fuse for shrapnel; bore-safe, super-quick and selective delay fuses for shell. The high explosive shell should be of one type only. It should be designed for maximum ballistic efficiency and should contain the maximum bursting charge compatible with that object. For cheap manufacture a semi-steel shell may be furnished, provided it has the same exterior ballistics as the standard shell. Two propelling charges should be furnished, a normal charge for about 11,000 yards range and a super-charge for maximum range. The proportion should be 90% of the former and 10% of the latter. The ballistics of the shell and shrapnel should be the same, if practicable; the ballistics of the round of ammunition should be the same regardless of the type of fuse used. A maximum rate of fire of 20 rounds per minute is deemed sufficient.

30. Practical. For the present arm brigades with 75 mm. material, Model 1916. . .50%, and 75 mm. (French) . . . 50°/₀. Continue experiments on carriage types, perfecting the split-trail carriage and studying the subject of a carriage for all round fire: continue experiments with projectiles for increase in range, power, and accuracy. Our time fuse is as satisfactory as any at the present time, but a mechanical fuse should be perfected. There is no requirement at the present time for more than one variety of delay action fuse for the 75 mm. gun. For shell the super-quick and short delay fuses only are required. The present super-quick fuse must be made bore-safe. It is not satisfactory in its present form. For motorized regiments rubber tired wheels are required.

31. Transport. Ideal. Mechanical transport is the prime mover of the future. It is most important that design, experiment, and test of self-propelling caterpillar types, also of caterpillar for draw-bar pull, of wheeled trailers for long rapid hauls, and of the development of similar ammunition

vehicles, be vigorously pushed. For normal use a maximum speed of 12 miles per hour is sufficient. The introduction of mechanical transport will undoubtedly cause far reaching changes in the types of gun carriages. It is not possible now to state just how far this will go or whether a gun mounted on a self-propelled vehicle or one mounted on some type of trailing vehicle; will be the final result. Both types may be necessary. It is urgent that study and development be vigorously carried on along these lines, as we are on the verge of changes fully as radical as the introduction of the long recoil field gun carriage, and the country first utilizing the new capabilities opened up by mechanical traction and the caterpillar, will have a great advantage in the next war. A limit of 4500 pounds behind the team has heretofore been universally imposed on artillery of this class. The corresponding limit in the future will probably be that imposed by pontoon bridges.

32. Practical. While there is no question that the tendency is towards complete motorization, the Board from a result of its investigation, does no feel justified at the present time in recommending complete motorization of all division artillery. Therefore, it is thought that four regiments of 75 mm. guns, (2 regiments of French Model 1897, and 2 regiments of U. S. Model 1916), should be immediately motorized; the remainder to be horsed; mechanical transport to gradually replace horse only after the tractor demonstrates its superiority in service. There are various limitations and imperfections in our present tractor equipment which it is believed can only be fully determined by a daily use of this equipment in service.

33. (b) Howitzer. Ideal. A weapon of about 105 mm. caliber on a carriage permitting a vertical arc of fire of from minus 5 degrees to plus 65 degrees, and a horizontal arc of fire of 360 degrees. Efforts should be made to develop a carriage which can be used interchangeably for the division light gun referred to above and this howitzer. The projectile should weigh about 30 to 35 pounds and should include both shrapnel and shell. A maximum range of 12,000 yards will be satisfactory. Semi-fixed ammunition and zone charges should be used, otherwise the ammunition should be similar to that provided for the 75 mm. guns.

34. Practical. For the present, brigades should be armed with the 155 mm. howitzer, Schneider, but active development and test should be prosecuted on a type as stated under "Ideal" above, and with ammunition and other accessories to it. Upon the development of the carriage as nearly approximating the ideal as may be practically possible, efforts should be made to secure quantity production in order that it may be incorporated in the division artillery as recommended. In addition a split-trail carriage for this howitzer should be developed.

35. Transport. The light howitzer should have the same means of transport as the light field gun and the same remarks heretofore made as to the probable future development of the field gun also apply to the howitzer carriage. For the present the 155 mm. Schneider howitzer regiments should be motorized. All testimony before the Board and all investigations of the Board emphasized the necessity of this.

Medium Field Artillery.

36. (c) Gun. Ideal. A caliber of between 4.7-inch and 5-inch on a carriage permitting a vertical arc of fire of from minus 5 degrees to plus 80 degrees; a horizontal arc of fire of 360 degrees. Shrapnel and shell weighing not over 60 pounds; maximum range 18,000 yards; with semi-fixed or separate

loading ammunition permissible. The normal charge should be established for about 12,000 yards. Propelling charge should be smokeless and flashless. The fuses should be time for shrapnel, with bore-safe, super-quick, and selective delay for shell. One type of shell designed primarily for maximum ballistic efficiency is sufficient. It should contain as large a bursting charge as possible. A normal propelling charge for 12,000 yards should be established with a super-charge for maximum range. The proportion should be 80% of the former and 20% of the latter. A maximum rate of fire of six rounds per minute is considered sufficient. The limits of weight formerly imposed on this class of matériel by horse traction will no longer exist, and while the Board is not prepared to set a definite limit of weight for future development, it is believed that it may be safely assumed to be not less than 12,000 lbs. for wheeled vehicles or 15,000 lbs. for caterpillars. A normal maximum speed of 8 miles per hour is considered sufficient.

37. Practical. Corps artillery should be armed with the present type 4.7 inch gun, Model of 1906, except that at least one regiment should be armed with the British type 5-inch guns purchased abroad. The Board is influenced in this decision by the quantity of ammunition on hand. It would have been recommeded that the bulk of the artillery be armed with British gun except that it is believed that the large stock of 4.7 inch ammunition on hand must be utilized. In any case, as there will be a large quantity of both types of material on hand for use in an emergency for a considerable period of time, it is believed that both types should be continued in service in order that the field artillery may retain their familiarity with them. The remarks made in regard to the development of a type of carriage under the division field gun also apply to the corps gun and, in addition, it is believed that experimental work should be carried on with a view of developing a satisfactory split-trail carriage. Experiments with projectiles for increase in range, power, and accuracy and development of fuses should be carried on as outlined for the division gun. The types of fuses recommended for the division gun apply also to the corps gun.

38. Transport. All corps guns should be fully motorized and wheeled trailers should be developed for long rapid hauls. Similar ammunition vehicles should be developed. The wheels for the gun carriage should be rubber tired.

39. (d) Howitzer. Ideal. A caliber of about 155 mm. on a carriage permitting a vertical arc of fire of from minus 5 degrees to plus 65 degrees; and a horizontal arc of fire of 360 degrees. It would be desirable to develop a carriage which can be used interchangeably for both corps gun and howitzer. The projectile should weigh not over 100 pounds and should be interchangeable with projectiles for other guns of this caliber referred to later on. High explosive shell only should be supplied. Two types of shell should be provided,—one for maximum bursting charge and one of comparatively inexpensive manufacture which may contain less explosive; the ballistics of both should, if practicable, be the same. The proportion should be 70% of the former and 30% of the latter. Maximum range should be 16,000 yards. Ammunition should be separate loading and related zone charges smokeless and flashless. Bore-safe, super-quick, and selective delay fuses for shell. The maximum rate of fire should be not less than 5 rounds per minute. A split-trail carriage should be developed, interchangeable if practicable with

that for the corps gun. Maximum speed the same as that of the corps gun, viz: 8 miles per hour.

40. Practical. The corps should be armed with the 155 mm. Schneider howitzer referred to above. The types of fuses for shell should be super-quick and long delay.

Heavy Field Artillery

41. (e) Gun. Ideal. A caliber of about 155 mm. on a carriage permitting a vertical arc of fire of from 0 degrees to plus 65 degrees; with a horizontal arc of fire of 360 degrees. A projectile weighing not over 100 pounds which should be interchangeable with that provided for the corps howitzer. High explosive shell only should be furnished. The self-propelled caterpillar unit offers a promising field of development for this type of gun, but a certain proportion should be retained on rubber tired wheeled mounts for rapid transportation; the maximum speed for the former type should be 6 miles per hour and for the latter type 12 miles per hour. Ammunition should be carried in original containers in trucks and tractor caissons. The conventional type of caisson is considered uneconomical and is obsolete for this caliber. The maximum range should be about 25,000 yards. A normal charge for range of 18,000 yards should be provided, with supercharge for greater ranges. The ammunition should be separate loading and the propelling charge smokeless and flashless; with bore-safe, super-quick and selective delay fuses for shell. The shell should be of two types; a shell of maximum ballistic efficiency with fair sized bursting charge(50 per cent); and a shell of inexpensive manufacture with as large bursting charge as practicable, inter-changeable with the 155 howitzer shell (50 per cent).

42. Practical. Arm with the present type 155 mm. G.P.F. and carry on experiments for type of carriage as outlined for division field gun. The fuses should be super-quick and short delay.

43. Transport. All artillery of this type should be motorized and test and experiment for ammunition vehicles to correspond with the types of carriages developed, should be carried on simultaneously.

44. (f) Howitzer. Ideal. A caliber of about 8 inches on a carriage permitting a vertical arc of fire of from 0 degrees to plus 65 degrees; and a horizontal arc of fire of 360 degrees. It would be desirable to develop a carriage which can be used interchangeably for the 155 mm. gun and the 8-inch howitzer; projectile should weigh not over 240 lbs.; the maximum range should be 18,000 yards; ammunition, separate loading; related zone charges, smokeless and flashless; shell only should be furnished which should be of two types, one of maximum capacity for bursting charge(50 per cent), and one of comparatively cheap manufacture with fair size bursting charge (50 per cent). For fuses, bore-safe, super-quick and selective delay should be furnished.

45. Practical. Use at present 8-inch material of British design which is on hand. The caterpillar treads which have been experimentally substituted for wheels are considered to be an advance and it is recommended that two batteries be so equipped for service test at once. Two types of fuses are required; the super-quick and the long delay.

46. Transport. All this material should be fully motorized. Ammuni-

tion should be carried in trucks and tractor caissons. A maximum speed of four miles per hour is sufficient.

Weapons of Greater Power

47. (g) Heavy guns. Ideal. There will be missions requiring the use of direct fire and of a projectile weighing more than that of the 155 mm. gun referred to above. Guns will also be required having a range of more than that considered feasible for the 155 mm. gun and there should, therefore, be provided a limited quantity of guns of a caliber of about 194 mm. to 8-inches firing a projectile weighing about 220 pounds. The maximum range should be 35,000 yards. The ideal carriage for such a gun would conform in its general characteristics to those outlined above for the 155 mm. gun, and such a gun and carriage should be developed and tested until a satisfactory type is evolved. The projectile should be high explosive shell of maximum ballistic efficiency. The fuses should be super-quick and short delay. Suitable ammunition vehicles should be evolved and they should be the same as for the 8-inch howitzer referred to above. The type of equipment overlaps in its use the field of the 8-inch gun referred to hereafter on a railway type of mounting. The Board has in mind the development of a caterpillar carriage in this case, and while the weights involved appear large for a road type of mount, it is in the general line of development and is one which must be followed out. No gun of this power and weight has so far been arranged for road mounting by any foreign country, but the French have actually completed one of this type for their 194 mm. gun; this gun, however, is of considerably less power than the one recommended by this Board.

48. (h) Heavy howitzer. Ideal. A caliber of about 9½ inches on carriage permitting vertical arc of fire from 0 degrees to 65 degrees and a a horizontal arc of fire of 360 degrees. The carriage should be of a type requiring as little preparation for firing as possible. No type of road mount is known which is satisfactory in this respect, but the Board has in mind the development of a caterpillar type. The maximum speed need not exceed 6 miles per hour. The maximum load should not exceed 20 tons. A certain percentage should be on wheeled mounts and the loads divided so that the maximum on four wheels will not exceed 12 tons. A projectile weighing not over 400 pounds, high capacity, high explosive shell, with maximum range of 25,000 yards, separate loading, related zone, smokeless flashless propelling charges, fuses bore-safe intantaneous and selective delay. Three kinds of high explosive shell are permissible; (a) one to secure the maximum ballistic effect with as large a bursting charge as practicable; (b) one with maximum bursting charge; (c) one of comparatively cheap manufacture with fair size bursting charge.

49. Transport. Ideal. Mechanical transport, caterpillar drawn. Continue experiments on caterpillar mounts with the idea of developing a satisfactory type. Corresponding ammunition vehicles should be developed.

50. Practical. The present design of 240 mm. howitzer should be continued in service. It is unsatisfactory in the length of time required to emplace for firing, but it represents modern practice reasonably well. The super-quick and long delay fuses should be furnished.

51. (i) Super guns. In the design of all artillery of this class, it is essential that the Seacoast Defense problem be considered, since this type of artillery should be suitable not only for use in the field, but also for use

along our coast against naval targets. For this reason, all carriages should be provided with means of obtaining all around fire, either from a position previously prepared, or from a temporary platform. This feature of all round fire in the case of large guns and howitzers, will doubtless be in addition to the regular means provided for firing the mount in the field against the stationary target. The design of the carriages should be studied with the view of obtaining a universal barbette mount that could be emplaced in the present seacoast emplacements, in simple auxiliary emplacements and with trucks under it forming a railway mount.

52. Gun. Ideal. A gun of 8-inch or 10-inch, 50 calibers in length, on railway carriage, permitting a vertical arc of fire of from 0 degrees to 50 degrees, a horizontal arc of fire of 360 degrees, a high explosive projectile weighing not less than 240 pounds for 8-inch or 510-pounds for 10-inch, with a maximum range of not less than 35,000 yards. Separate loading ammunition, smokeless flashless charges, bore-safe, instantaneous and selective delay fuses. Maximum time for occupying a position under actual field conditions should not exceed one hour for the 8-inch or four hours for the 10-inch. The maximum rate of fire should not be less than one shot every two minutes.

53. Transport. Railway carriages adaptable for transportation over standard gauge track (carriages should be equipped with narrow gauge trucks, 60 cms. (24 inches). Axle load should not exceed 17 long tons per axle. The mount should lie entirely within the International Clearance Diagram, and thus be suitable for transportation over European railways. Provision for both American M.C.B. standard couplings and the French type of couplings should be provided.

A gas electric locomotive of about 400 horse power capable of speeds up to 25 miles per hour should be developed for use with this type of artillery. Ammunition cars suitable for the storage of powder and projectiles are required. A complete repair shop should be provided. Tool equipment to be capable of making repairs on this type of artillery.

54. Practical. There are now being completed in the United States, 36 railway carriages of the Schneider type for mounting the 10-inch Seacoast guns, permitting a vertical arc of fire from 10 degrees to 55 degrees. The gun gives an estimated range of 24,000 yards with a 510 pound projectile. Also 37 8-inch guns have been mounted on railway mounts of the above characteristics except as to range. Range of these 8-inch guns with 200 pound projectiles is 20,000 yards. Arm units with these available guns on railway mounts. An experimental 8-inch 50-caliber railway mount or 10-inch 50-caliber railway mount, should be manufactured in order that the proper type may be selected.

55. Gun. Ideal. A 14-inch gun 50 calibers long on a railway mount, permitting a vertical arc of fire from 0 degrees to 50 degrees, and a horizontal arc of fire of 360 degrees, from prepared position, or to 15 degrees when fired from curved track; a high explosive shell weighing not more than 1400 pounds with a maximum range of 40,000 yards, separate loading ammunition, smokeless flashless charges, bore-safe instantaneous and selective delay fuses. Time required for firing from prepared position not to exceed one hour. From unprepared position not to exceed 8 hours.

56. Practical. Arm units with available guns on railway mounts.

57. (j) Howitzer. Ideal. A 12-inch howitzer 20 calibers in length on

carriage providing vertical arc of fire from 25 degrees to 60 degrees and a horizontal arc of fire of 360 degrees. A high explosive shell weighing about 700 pounds with a maximum range of 25,000 yards, or a 1046-pound shell with a maximum range of about 18,000 yards. Related zone charges, smokeless flashless powder, bore-safe instantaneous and selective delay fuses. Time to occupy field positions not to exceed one hour, for all around fire.

58. Transport. Ideal. Same as above.

59. Practical. Arm units with available howitzers on railway mounts.

60. Howitzer. Ideal. 16-inch 25-caliber howitzer mounted on railway mount permitting a vertical arc of fire from 25 degrees to 65 degrees. A horizontal arc of fire of 360 degrees from a prepared position or 10 degrees from a temporary position. High explosive shell weighing not less than 1600 pounds with a maximum range of 30,000 yards, related zone charges, smokeless flashes powder, bore-safe instantaneous and selective delay fuses.

61. Transport. Ideal. Same as above.

62. Practical. The manufacture of a pilot 16-inch 25-caliber howitzer on railway mount should be inaugurated.

Other Artillery

ANTI-AIRCRAFT GUNS:

63. (k) In the recommendations of the Board under the heading "Ideal" it will be noted that the maximum elevation stated to be desirable has been made 80 degrees for the Division and Corps guns and 65 degrees for the heavier types. This is in view of the greatly increased air activity to be expected in the future and is with the expectation that the division and corps guns will be often used against airplanes and the heavier types against balloons. These ideal types are, however, not yet practical and the following special anti-aircraft equipments are necessary. Moreover, special anti-aircraft weapons will probably always be required on account of the need for a higher initial velocity than is permissible in a general purpose gun.

64. Light gun. Ideal. Caliber of about 3-inch with initial velocity of at least 2600 f.s.; semi-automatic breech block, mounted on carriage permitting 80 degrees elevation and 360 degrees traverse; projectiles weighing not less than 15 pounds, of one type high explosive shell with maximum ballistic qualities and as large explosive charge as possible; fixed ammunition; smokeless flashless powder, mechanical fuse. In this type every effort must be made to increase rate of fire and decrease time of flight; this latter is limited only by considerations of a reasonable accuracy life for the gun.

65. Practical. Arm units with present 3-inch anti-aircraft equipment; continue experiments leading to the development of the ideal.

66. Transport. Ideal. Caterpillar mount or caterpillar trailer mount drawn by caterpillar tractor, each unit to permit a sustained speed of 12 miles per hour.

67. Heavy gun. Ideal. A caliber of 4.7 inches to 5 inches, with initial velocity of at least 2600 f.s.; semi-automatic breech block; mounted on a carriage permitting 80 degrees elevation and 360 degrees traverse; projectiles weighing not less than 45 pounds; one type high explosive shell with maximum ballistic qualities and as large bursting charge as practicable; fixed ammunition; smokeless flashless powder; mechanical fuse. In this type every effort must be made to increase rate of fire and decrease time of flight; this

latter is only limited by a reasonable accuracy life to be obtained for the gun.

68. Practical. Arm units with present 4.7-inch anti-aircraft gun and continue experiments leading to the development of the ideal.

69. Transport. Ideal. Self-propelled caterpillar mount permitting sustained speed of 8 miles per hour with maximum weight not to exceed 10 tons, trailers to be provided for long and rapid hauls.

PACK ARTILLERY:

70. (l) Gun. Ideal. A caliber of about 3 inches; to use projectiles of division gun, if possible; to permit elevation of at least 45 degrees; a range of not less than 5000 yards; to pack in loads about 225 pounds per load exclusive of pack equipment; to be equipped with panoramic sight; ammunition semi-fixed, flashless, smokeless, with about four zones; capable of being pulled on wheels by the gun crew on normal ground, and for short distances over any ground. A shield is unnecessary.

71. Practical. Continue the present 75 mm. Vickers equipment in service. The material is, however, of an old type and it is one of the items of artillery in most urgent need of development.

INFANTRY ACCOMPANYING GUN:

72. (m) Gun. Ideal. A gun of about 2.5 inches caliber firing a projectile of about 10 pounds weight, mounted on a carriage, permitting elevation of from minus 5 degrees to plus 50 degrees and having a field of fire of not less than 6 degrees. The carriage should be designed so that it may be divided into loads, the maximum of which should not exceed 100 lbs. The gun and carriage complete to weigh not more than 300 pounds and to be arranged so that it can be readily hauled by two men over sod. The complete equipment must be capable of being man-handled in trenches. The gun should be effective for direct fire at 2500 yards. A telescopic sight should be furnished and the ammunition should consist of high explosive shell with maximum bursting capacity and instantaneous fuse. A cannon similar in general but of less power was examined in Italy and two equipments with 6000 rounds of ammunition were ordered through the Military Attache's office in Rome.

73. Practical. Utilize the present 37 mm. guns on hand. These are deficient in the fact that the projectile is too light. In the opinion of the Board a cannon of the type described above would have the mobility of the 37 mm. gun and would provide in addition a most desirable substitute for the 3-inch Stokes trench mortar as used in the present war.

74. Transport. These equipments will be handled by men only except on the march when they should be loaded in trucks.

TRENCH ARTILLERY:

75. (n) As stated, the Board is of the opinion that the infantry accompanying cannon can be made to serve the purpose of the light trench mortar as used in the present war. It is believed that a field exists, in addition, for a trench mortar of about 6-inches caliber firing a projectile weighing about 50 pounds and having a maximum range of about 4000 yards. So far as known, such a mortar has not been developed. It is recommended that experiments along this line be carried on. The mortar should be fired at elevations of from 40 degrees to 65 degrees. The 6-inch Stokes mortar used in the present war is not considered satisfactory due to its lack of range and its great weight; also its type of mounting was such that a change in elevation affected the traverse, and vice-versa. The principal value of the

trench mortar, in the opinion of the Board, lies in its cheapness and the rapidity with which a large number may be constructed. Therefore, the greatest simplicity in the design should be maintained.

ANTI-TANK CANNON:

76. (o) For tanks as they existed at the end of the past war a caliber 50 machine gun with a bullet weighing about 700 grains, together with the 75 mm. field gun were efficient. There was being developed armor piercing ammunition for the 37 mm. gun. In the opinion of the Board, the 37 mm. gun with armor piercing shot, the caliber 50 machine gun and the 75 mm. field gun, are suitable weapons for the attack of tanks in their present stage of development. There is, however, every reason to expect that the future development of tanks will be along the lines of better armor protection and of carrying more powerful cannon. It is, therefore, anticipated that in the future their development will be such that neither the caliber 50 machine gun nor the 37 mm. gun will be sufficient for their attack. It is believe that their armor protection will be such that it will have to be attacked by a base fuse shell, probably of about 75 mm. caliber. For the present, it is recommended that armor piercing ammunition be issued for 37 mm. cannon for anti-tank protection especially as this caliber will be retained for the present as the infantry accompanying gun.

PART II

V. ARTILLERY TRANSPORT

General Discussion

77. Mechanical transport is in such a state of development in this country that there is no need in dwelling upon its numerous advantages over animal draft. It is, however, pertinent to give a brief outline of the extent of its employment by foreign governments, while stating that the United States is far in advance of all other world powers in respect to self-propelled vehicles applied to artillery transport.

GERMAN: Wheeled tractors of the farm and road repair type, with low speed, great power and extreme weight for hauling heavy weapons.

Wheeled trucks of the two-wheel-drive type with medium speed, medium power and normal weight, carrying anti-aircraft guns, directly and permanently mounted upon the chassis.

ITALIAN: Wheeled trucks, similar to the German as anti-aircraft gun mounts.

Wheeled tractors of two-wheel-drive type, medium power, speed and weight for hauling heavy weapons.

BRITISH: Rear-wheel-drive trucks, four-wheel-drive trucks, and a limited number of the heaviest American commercial farm caterpillars for hauling heavy weapons.

It is noted that these nations confined themsleves, for the most part, to wheeled vehicles, which type at once limits mechanical artillery transport almost entirely to good roads.

FRENCH: While using four-wheel-drive trucks of great power and mobility throughout the war the French finally recognized, during 1917, the necessity and advantage of cross-country mechanical transport as evidenced by their development of platform caterpillars for carrying their 155 mm.. howitzer mounted on its wheeled carriage, and for towing other heavier weapons; of cargo-carrying caterpillars for ammunition and other supply purposes; and of self-propelled caterpillar gun mounts for heavier guns.

78. While these nations were employing limited motorization, the whole project appealed to them as a thing apart from animal transport and apparently, with the possible exception of the French, who later realized the great possibilities of the caterpillar tractor, no idea existed relative to replacing animal draft by the motor driven vehicle; they considered each a valuable means of bringing the weapon to the proper place at the right time.

79. The United States approached the subject of motorization from the standpoint of obtaining a better means of transport for its artillery than offered by the draft animal. The result has been a mechanism which directly replaces the team in draft, giving at the same time a better performance, because of the fact that while animal transport, especially with lighter weapons, possesses great mobility, it does not possess a sustained or persistent mobility; exhaustion surely renders it inactive after a limited period and the time required for recuperation is fatal, if coincident with a critical point in the military operation. This question of exhaustion of animal transport is best illustrated by analyzing the mechanics of the forward push or breaking through, which is the object sought for in the struggle for a military decision. Our offensive military machine must be designed not only to fit every phase in the mission of breaking through but also to remain intact when the breaking through has been accomplished.

80. In the completest conception of an offensive, the machine starts from rest. It is at this time that the offensive mass is at its maximum. The preliminaries in an offensive combat are designed to break down the physical and moral resistance of the enemy, the opposing friction, so to speak, and to make subsequent progress as economical as possible and as rapid as desirable. Motion, or velocity of offensive progress, commences when the enemy's organized resistance begins to yield. It is at this time that the energy—that is, the mass and the movement of the offensive—expresses itself in progress toward the desired goal, namely, the break through.

81. In the second phase, we find the machine in motion. It is now that the varying rates of speed of the different combat agencies begin to impress us most particularly. It is now that the time element, more or less inconspicous in the first phase, begins to be a dominating one. It is now that transportation—supplies, ammunition, guns, etc.—has to move. Infantry will certainly move; across country, it is the most mobile combat agency. Velocity there will certainly be in abundance as the lighter lines progress into the enemy's country, but mass and, therefore, energy will be lacking unless artillery and supplies keep up. An advance goes well enough in the area covered by artillery fire. Beyond the action of artillery, however, the enemy is unhampered in his defensive and counter-offensive dispositions. The mass of the enemy's resistance increases to a point where it is not possible to penetrate it with a rapidly diminishing offensive mass, no matter how high the velocity of the latter may be. The offensive lacks energy due to the absence of those agencies which made the orginal advance possible; exhaustion exacts its penalty.

82. During the phase of motion the animal is called upon for its maximum exertion, while receiving the minimum of care. Exhaustion is the natural result and, therefore, as is borne out by the analysis of many experiences of

the European War, we may say that against an organized enemy a break through is not possible with animal transport alone.

83. The difference in national ideas of animal and mechanical draft is probably due to the road conditions existing here and abroad, the European having at his disposal a vast network of excellent roads with speed as the only limitation to the horse, his idea of other transport being a fast moving vehicle whose use is merely occasional; on the other hand, the American artilleryman is confronted with roads which are little better than the untraveled cross country. The solving of the transport problems has placed us in a far better position to meet all warfare conditions than other nations because of the fact that we now need not confine our activities to the highways but have at our disposal the vast area of untraveled off-the-road terrain, leaving the roads open for the high speed motor vehicles of the supply departments.

84. In other words, we had developed the use of man and animal power to practically the limit. The use of good roads and the use of railroads is well understood, but now we are in a way to conquer the broadest field, that is, cross country, by the use of mechanical transport, allowing the great duty which was placed on good roads and the railway as avenues for artillery transport to be handled more particularly by cross country mechanisms.

Gasoline Propelled Vehicles

85. The transportation limitations of the above can be generally stated as follows: The rear wheel drive truck and high speed motor car can be operated on good roads.

The four wheel drive truck and light motor cars can be operated on almost all classes of roads.

The caterpillar can be operated on all classes of roads and also in the open country.

MOTOR CARS:

86. The war has brought about no radical changes in motor cars. About the most that can be said on this subject is that certain commercial cars have shown greater strength of parts and ease of operation than others. They are, therefore, favored for military purposes.

MOTOR TRUCKS:

87. When motor trucks were first used for military purposes the commercial types were naturally used. The two wheel drive type was the first to appear; later, to meet a demand for utilizing to the best advantage the full power, the four wheel drive type made its appearance in the commercial world. When the two types were tested in the early days of the Mexican Expedition, real dependence was placed on the four wheel drive trucks, there being instances where whole trains of two wheel drive trucks were stalled. At a later date when the roads had dried and improved, the two wheel drive type made a better showing and came out with a better reputation.

88. However, the artillery is most interested in the type of truck that is best suited for bad road conditions. The United States Marine Corps which has had to use motorized field artillery for some of its minor operations adopted, after many tests, the four wheel drive truck to handle its artillery. Throughout the entire war, the English, French, and Russian Governments purchased considerable quantities of trucks driven on all four wheels for use in their artillery service, and as late as July, 1918, the French made an urgent demand on the American E. F. for 300 such trucks. The four wheel drive

truck has such power, application, and weight distribution as to assure movement of the vehicle if traction can be obtained even by one wheel.

89. Up to the fall of 1917, there had not been found a type of four wheel drive truck as refined in mechanical details as some of the higher types of two wheel drive trucks. This was natural, as the development of the four wheel drive truck came later than the two wheel drive. However, the Ordnance Department undertook the development of a four wheel drive truck that would not have any of the defects of the four wheel drive commercial types. This truck was ready for production in May, 1918, and was recommended by a board of officers from practically every department of the service for adoption as the standard type of four wheel drive truck for the United States Army (See Par. 30, S.O. 91, W.D., April 18, 1918).

In the opinion of the board, the four wheel drive two wheel steer type of truck is the only heavy cargo carrying wheeled vehicle which is adequate to meet artillery needs in the battery, battalion, and the regiment as well as in the artillery ammunition train, and until definite recommendation to this effect is approved, artillery will be burdened with a heterogeneous mass of trucks whose use is confined almost entirely to good roads.

CATERPILLARS:

90. The superiority of the caterpillar over all other mechanical prime movers across country may be realized when we consider the essential features embodying its construction. The frame supporting the power plant with the necessary power transmission members is mounted upon small wheels; these wheels, instead of having direct contact with the ground, travel continuously upon a track, the rails of which are permanently mounted uopn a flat, broad surface. This surface or tread corresponds with the sleepers or cross ties of the railroad, and is of such width as to secure very low unit pressures upon the ground. The track with its tread is formed into an endless belt which is driven by a sprocket identically as the bicycle chain. The whole vehicle, therefore, may be said to constitute a wheeled mechanism which lays its own track as it moves over the ground. Further, by articulating the track and the frames or trucks which mount the wheels, the varied ground surfaces are accurately conformed to—a feature which further insures traction. Again, the power is applied in such a manner that an individual drive is assured on each of the two tracks. With such a structure movement is assured over very soft ground owing to low unit pressure, which is usually about 5 lbs. per square inch. The caterpillar can span wide gaps or ditches or climb steep slippery grades. The grip on the ground or traction is secured by cleats or grousers which project to a height of approximately three inches from the surface of the treads. With the grousers removed the caterpillars do not seriously damage hard roads. The above advantages make the caterpillar the only logical prime mover to replace the team in draft.

HISTORY OF ARTILLERY MOTORIZATION IN U. S.

91. Serious and practical experiments with the caterpillar for artillery transport were started in the United States by the Ordnance Department in 1914, and the next year a commercial farm tractor of the most promising type was tested by the Field Artillery Board, resulting, in 1916, in the complete re-design of a number of such vehicles to adapt them to artillery field service, and in the actual motorization of one medium heavy battery in this country and one medium heavy regiment in Honolulu. This re-designed

caterpillar still contained many small weaknesses, the elimination of which led in 1917 to the development and manufacture of the present artillery tractors.

92. The progress in artillery motorization is best indicated by the recommendations and results obtained by Boards of Artillery and Ordnance officers; these recommendations were arrived at after long, careful study, test and investigation, not only in the laboratory but also in the field under simulated and actual war conditions. The authority in each case is given, together with the substance of the recommendations of the various boards.

93. Special Orders No. 98, W. D., 1917, par. 51, appointed a board to "consider the question of motor traction for Field Artillery."

This board recommended:

(a) The motorization of the 4.7″ gun,
(b) The motorization of the 8″ howitzer,
(c) The use of rubber tires on all Field Artillery matériel,
(d) The formation of a pool of 30 artillery tractors for each combat division,
(e) Sending a member of the Board to France to investigate the motorization of the 6″ howitzer.

These recommendations were approved by the Secretary of War, and the several supply departments were directed to put them into effect.

94. The result of the investigation in France was Special Orders No. 83, Par. 7, G. H. Q., A. E. F., 1917, appointing a board to "consider and report upon the question of motor transportation for 6″ howitzer material."

This board recommended:

(a) The motorization of the 6″ howitzer,
(b) The retention of the divisional tractor pool,
(c) The development of motor transport for artillery in all forms.

These recommendations were approved by the Commander-in-Chief, A. E. F., in Cablegram 149, paragraph 15, to The Adjutant General, Sept. 11, 1917, and the supply departments were directed to comply.

95. Par. 69, Special Orders No. 242, W. D., 1917, appointed a board to continue the work of the Field Artillery Motor Traction Board, "to consider all questions of motor traction for Field and Heavy Artillery."

This board recommended the motorization of:

(a) The 6″ howitzer,
(b) The 4.7″ gun,
(c) The 9.2″ howitzer,
(d) The 240 mm. howitzer.

The board further recommended:

(a) The use of wheeled trailers in certain motorized organizations for rapid transport of the tractors.
(b) The use and general requirements of the staff observation and reconnaissance cars.

These recommendations were approved by the Secretary of War, and the supply departments were directed to comply therewith.

Based upon data collected by the above boards, the General Staff drew up Tables of Organization for motorizing the 155 G.P.F., and the 5-inch and 6-inch seacoast converted guns.

96. An Artillery Board at G. H. Q., A. E. F., after practical test recommended:

(a) The motorization of 50% of the 75 mm. gun regiments in each division;

(b) The motorization of the caisson companies of the ammunition train.

These recommendations were approved by the Commander-in-Chief, A. E. F., in cablegram No. 1771, par. 1, October 9, 1918.

Weapons of various sizes have also been placed on experimental self-propelled caterpillar mounts, namely, the 75 mm. gun, the 155 G.P.F., the 8" howitzer and the 240 mm. howitzer.

97. To date, with the exception of 50% of the 75 mm. guns in the combat divisions, the motorization of all Artillery mobile weapons has been authorized and would have been put into effect had the war lasted a few months longer, or if ship bottoms has been available during the war. At the cessation of hostilities in 1918, sufficient tractor equipment had not been delivered in France to carry out this project; this was unfortunate, for many of our artillery personnel had had experience with commercial farm caterpillars, with their serious defects and unadaptibility to artillery transport, and had consequently formed erroneous opinions based on such performance. It is, however, interesting to note the reports of those artillerymen who were fortunate enough to have received even a small proportion of the adequate allowance of motor equipment in its present stage of development for artillery purposes.

TYPES PRODUCED BY ORDNANCE DEPARTMENT

98. The Ordnance Department has, up to the present time, accomplished the following general mechanical development with respect to artillery motor equipment:

(a) An efficient 10-ton artillery tractor for pulling heavy gun loads has designed, tested, and is in quantity production, i.e., 2800, of which 933 are in France.

(b) An efficient 5-ton artillery tractor for pulling medium gun loads has been designed, tested, and is in quantity production, i.e., 4000, of which 1018 are in France.

(c) Efficient heavy mobile repair shops have been designed, tested, and put into production, i.e., 17 shops of 2 sections each, one of which is in operation in the occupied zone of Germany.

(d) An efficient artillery repair truck has been designed, tested, and is in quantity production, i.e., 1332, 420 of which are in France.

(e) An efficient 3-ton four-wheel drive truck has been designed, tested, and adopted as standard for use in the army.

(f) Caterpillar trucks to replace wheels on certain heavy guns.

(g) The following have been designed, built, and are being tested:

2½ ton tractor,

Heavy motorcycle for artillery,
Self-propelled gun mounts for various weapons,
Cargo carrying caterpillars or tractor caissons, Cargo caterpillar trailers.

It can be stated with respect to (a), (b), and (c), that the United States is far in advance of all other world powers.

TYPES RECOMMENDED TO BE DEVELOPED

99. The maximum speed for draw bar tractors should fall within a definite scale of approximately 12-8-5-3 miles per hour, with such a total reduction in each case for low gear as to provide a sure means of pulling out under all conditions. It is apparent that when good roads exist and traffic conditions are such as to allow their employment by artillery, a great loss of time is involved where long marches are necessary. The only solution is the employment of sprung, rubber-tired wheeled vehicles to transport the tractors and gun matériel, using a high speed wheeled truck as the prime mover. With such an arrangement, sustained movement over long periods at a speed of 15 m.p.h. may be economically accomplished. At the present stage of development, the trailer is the only available medium, but we can easily conceive of the application of sprung rubber-tired wheels to the tractor as an inherent part of its construction, in such a way as to permit the tractor to be quickly formed into a wheeled trailer; this, however, still requires the use of a wheeled truck as a means of transport—the next and ultimate step is to utilize the power plant of the tractor to drive its self-contained wheels. We will then have a self-propelled vehicle capable of operating as a caterpillar over cross country terrain and, also, at a moment's notice, capable of conversion into a truck operating at high speed on good roads.

100. While improving the caterpillar truck tractor, gun design will also progress; but with the weapon upon its wheeled carriage, a point will soon be reached where no improvement is possible. In all probability such a weapon and carriage will embody the split-trail feature, large angles of elevation and traverse, lightness coupled with stability and high power, but such a unit is not the limit of progress for we have the broad field presented by the possibilities of the gun mounted directly upon a self-propelled vehicle. Already, the self-propelled caterpillar gun mount is well along in the experimental stage and has passed to fact from fancy, and while the weights are excessive, the gun traverse limited, and slight relaying necessary, the results arrived at indicate final sucess in the near future. This success will be realized in a gun using, possibly, a pedestal mount, possessing perfect stability, all round fire, 90 degrees elevation, mounted upon a caterpillar truck tractor.

101. While it is readily conceivable that in the future all weapons will be so constituted and that experiment should be pushed to the utmost in this direction, it is essential that, for the present, there be developed to the minutest detail the draw-bar vehicles now existing and already in a safe state of perfection, utilizing these to the best advantage in conjunction with the weapons now at our disposal. To carry out this scheme, we must augment the existing equipment along the present lines in order that there may be a suitable range of tractors to move the weapons now in use.

TRACTORS:

102. To augment properly the existing types it will be necessary to develop the following:

(a) A small cargo carrying caterpillar without power plant, to be pulled by two men as a cart, with the tongue operating ratchets to drive the tracks when very difficult terrain is encountered; such a vehicle is primarily an ammunition carrier whose use is necessarily limited to stabilized warfare.

(b) A small unit having wheels or caterpillar treads, driven by a very light engine, the whole being operated by a man on foot, total weight being such that it can be readily man-handled by the operator; this vehicle being used for transport of heavy machine guns, infantry accompanying guns, ammunition service, and for laying wire.

(c) A light weight tractor to fulfill the one incomplete detail lacking in motorization, i.e., the motorization of the individual man. This tractor would have a very low center of gravity, 40 inches wide over all, articulated tracks approximately 6 inches by 8 feet, with small body for carrying 2 men or 500 lbs., water cooled engine capable of operating under water and at all possible tipping angles, with speed ranges from a sure low reduction of 3, 8 direct-drive, 12 over-drive, miles per hour. This tractor to be designed for replacing the horse of individually mounted men, for use in reconnaissance, for pack transportation including machine and mountain guns, for transport of ammunition, laying wire, etc.

(d) A heavy tractor similar to the present 10 ton type, embodying long track, great power, slow speed, no armor or auxiliary front steering wheel, total weight approximately 15 tons, for pulling loads of 18 tons maximum.

103. In general, the ranges covered by the proposed and existing equipment will appear as follows:

The tractor cart, light loads up to 200 lbs.;the ¼ ton tractor replaces the riding horse or carries loads not exceeding 500lbs.; the 2½ ton tractor replaces the six horse team or hauls loads not greater than 6000 lbs.; the 5 ton tractor replaces the eight horse team or hauls loads up to 12,000 lbs.; the 10 ton tractor, loads of 24,000 lbs.; and the 15 ton tractor, loads of 36,000 lbs.; maximum.

TRUCKS:

104. The four wheel drive truck of 3 tons cargo carrying capacity is entirely suitable for the corps and army artillery, but due to its weight is not entirely suitable for divisional motorization; for this purpose a four wheel drive truck of approximately 1 to 1½ tons pay load capacity is necessary in order to operate satisfactorily over very bad roads or unfavorable terrain. The tire may possibly be pneumatic 36"x6", compound filled to prevent puncture, as ordinary pneumatic tires are not recommended for field service cargo carriers. The need for the development of such a vehicle has been felt for many years in connection with the motorization of the lighter weapons.

TRAILERS:

105. Sufficient wheeled trailers now exist to cover practically every requirement, but our great effort should be in the development of the caterpillar trailer. Such a vehicle with a cargo capacity of 1½ tons should be designed, tested and put into production, to replace the 75 mm. gun and light field howitzer caissons in motorized units. A 3 ton cargo caterpillar trailer is now being tested and should be perfected to replace the caissons in 155 mm. howitzer and 4.7" gun units. The horse sections of the divisional

ammunition trains should be replaced by tractors pulling caterpillar trailers.

TRACTOR CAISSONS:

106. The self-propelled cargo carrying caterpillars, while very useful, are deemed of too great weight to apply to division or light corps weapons, but may be advantageous for heavier gun equipment, especially those normally rated at a capacity of 3½ tons, which can readily maneuver over ordinary open country with a load of five tons. The heavier vehicle normally rated as a five ton carrier is thought to be entirely too heavy.

SELF-PROPELLED GUN MOUNTS:

107. While there is great promise for such mounts, those at present in existence and under test are, for the most part, excessively heavy. The most promising at this time is the 75 mm. gun mounted on an approximation of the 2½ ton tractor. This mechanism, when carried on a 4-ton trailer and hauled by the 3-ton four wheel drive truck, is capable of going over good roads at considerable speed, and after being demounted from trailer can proceed across country under its own power. It has, therefore, important strategic and tactical uses.

108. The 155 mm. G. P.F. self-propelled mount also presents immediate possibilities, especially when we relize that to fire, the vehicle simply has to come to rest, with the power plant running, whereas, upon its present wheeled carriage, several hours are normally required to prepare the firing emplacement.

109. These two mounts, the 75 mm. and 155 mm. guns, should be immediatelydeveloped to the utmost, paying particular attention to mobility and lightness consistent with strength and stability.

110. Caterpillar tracks replacing gun carriage wheels have been tested here and in the A. E. F. with great success, especially on heavy howitzers. At present they should be applied only to the 8-inch howitzer carriage.

Complete Plan of Artillery Motorization

111. The following tables set forth artillery motor equipment already adopted, that being developed and that proposed to carry out the expansion of the present scheme, together with the application and general characteristics of each:

GENERAL CHARACTERISTICS

Caterpillar Types

Venicle.	Draw Bar Pull lbs.	Cargo Capacity	Speed M.P.H. Min.	Max.	Remarks.
Tractor cart‡		200 lbs.	1	4	Operated by man on foot.
¼ T. Tractor‡		500 lbs.	3	12	Replaces riding horse of individually mounted man.
2½ T. Tractor†	4000		3	11-12	
5 T. Tractor*	7000		3	8	
10 T. Tractor*	10,000		3	6	
15 T. Tractor‡	15,000		1	5	

Tractor Caisson Mark VII†	3½ T.	1½	4	Replaces caissons in heavy batteries.
Tractor Caisson Mark VIII†	5 T.			Not thought practicable due to excessive weight.
Trailers.				
3 ton Caterpillar Trailer†	3 T.			Replaces caissons in medium heavy batteries.
Light Caterpillar Trailer‡	1½ T.			Replaces caissons in division artillery.
Wheel Types.				
Ord. Standard 8000 4-wheel drive*	3 T.	3	12	
Light Four Wheel Drive‡	1½ T.	3	15	
Heavy Motorcycle with Sidecar.†	500 lbs.	3	50	
Trailers.				
3-ton Trailer*	3 T.			
4-ton Trailer*	4 T.			
10-ton Trailer*	10 T.			Transport of 10 ton tractors etc., in heavy batteries.

* Adopted.
† Under test and developing.
‡ Proposed.

APPLICATION.

Tractor Cart.‡	Wire Reels Heavy Machine Guns Infantry Accompanying Gun
¼ *Ton Tractor.*‡	Misc. Pack Transportation Heavy Machine Guns Mountain Guns Replaces horse for individually mounted men. Wire Reels

2½ Ton Tractor.†	75 mm. Gun	
	Light field howitzer	
	Reel Carts.	
*5 Ton Tractor.**	155 mm. Howitzer	
	4.7″ Gun	
	9.2″ Howitzer	breaking into 3 loads.
	240 mm. How	
*10 Ton Tractor.**	8″ Howitzer	
	155 G.P.F.	
	9.2″ Howitzer	breaking into 3 loads.
	240 mm. How	
	Salvage.	
15 Ton Tractor.‡	5″ Seacoast	
	6″ Seacoast	
	194 mm. Gun	
	Salvage	
Tractor Caisson-Mark VII†	Ammunition transport with battery, 155 G.P.F. tractor hauled or tractor mounted, an army artillery.	
3 Ton Caterpillar Trailer.†	Ammunition transport with battery, 4.7″ and heavier guns and howitzers.	
Light Caterpillar Trailer.‡	Ammunition transport with battery.	
	75 mm. Gun	
	Light field howitzer.	
*4-Wheel-Drive Standard Trucks.**	Army and corps artillery.	
	All uses.	
Light 4-wheel-Drive Truck.‡	Divisional Artillery.	
	All uses, including Ammunition Trains.	

* Adopted.
† Under test and developing.
‡ Proposed.

These charts indicate that certain vehicles are so closely allied that, excepting very special cases, we may follow a general principle of grouping in motorization.

The Division.
2½ ton tractor,
1½ ton caterpillar trailer,
1½ ton four-wheel-drive truck.

The Corps.

5 ton tractor,
3 ton caterpillar trailer,
3 ton four-wheel-drive truck.

The Army.

10 ton tractor,
3½ ton tractor caisson,
3 ton four-wheel-drive truck,
10 ton wheeled tractor for transport of tractors on good roads.

112. From this general grouping of transport vehicles, is formed the following practical table for the general scheme of motorization(Page 105):

IMMEDIATE APPLICATION OF THE ABOVE PLAN.

113. The following recommendations are based upon experience abroad, reports of motorization boards, tests and data resulting from experiment and research, and recommendations of artillery higher commanders.

(a) The immediate motorization of all weapons larger than the 75 mm. gun and 4-inch howitzer for use as follows:

1st The Regular Service,
2nd The Reserve,
3rd The National Guard,
4th The several educational institutions.

(b) The immediate motorization of the 75 mm., 3" gun and division howitzer for use as follows:

1st The reserve,
2nd The National Guard,
3rd The several educational institutions.

(c) The motorization when conditions warrant of:

1st The 75 mm. or 3" guns and 4" howitzers in the division,
2nd The horsed sections of ammunition trains, employing for such motorization, vehicles having the same tactical mobility as horse drawn carriages.

(d) The adoption, as standard vehicles, with such minor modifications as war experience has indicated, of:

1st The 10 ton artillery tractor,
2nd The 5 ton artillery tractor.

(e) The adoption, to the exclusion of other types of cargo trucks, of the four wheeled drive, two wheel steer type, with some form of steel cargo body:

1st For artillery use,
2nd For artillery ammunition trains.

SPECIAL RECOMMENDATIONS

114. (a) That motor equipment prescribed for artillery transport must be sufficient to maintain a prolonged rapid advance and must be of the best and most suitable types.

(b) Sufficient special motor vehicles of all types should be retained in service, or contracts completed, to completely equip all contemplated regular and reserve artillery organizations.

(c) That ample reserve of spare parts for motor equipment belonging to tactical organizations be maintained, and that ample spare parts be actual-

Weapon	Gun Transport	Ammunition transport with firing Battery	Other battery ammunition transport.	Baggage Rations, Fuel, Water, Misc. Supplies.	B. C. Detail Special Detail, & c., Reels, etc.
75 mm. Gun Light Field Howitzer	2-½ ton Tractor	2-½ ton Tractor & 1-½ ton Caterpillar Trailer.	2-½ ton Tractor and 1-½ Quad Truck, 1-½ ton Caterpillar Trailer	1-½ ton Quad Truck	½ ton Tractor and Caterpillar Cart and 2-½ ton Tractor with Reel Cart.
4.7" Gun 155 mm. Howitzer	5-ton Tractor	5-ton Tractor and 3-ton Caterpillar Trailer.	5-ton Tractor & 3-ton Caterpillar Trailer and 3-ton Quad Truck.	3-ton Quad Truck	Do.
155 mm. Gun 8" Howitzer 9.2" Howitzer 240 mm. Howitzer	10-ton Tractor	10-ton Tractor and 3-ton Caterpillar Trailer. 10-ton wheeled trailer for rapid transport of tractors & tractor trailers on good roads, pulled by Quads from reserve.	3-½ ton Tractor Caisson and 3-ton Quad Truck.	3-ton Quad Truck	Reconnaissance and Staff Observation cars & motorcycles & 2-½ ton Tractor with reel cart.
194 mm. Gun	15-ton Tractor	3-½ ton Tractor Caisson.	3-½ ton Tractor Caisson and 3-ton Quad Truck.	3-ton Quad Truck	Do.
			SPECIAL CASES		
75 mm. Gun Self Propelled Mount.	3-ton Quad Truck 4-ton Trailer	1-½ ton Quad Truck together with (2-½ ton tractor and 1-½ caterpillar trailer) transported by 3-ton Quad Truck and 4-ton Trailer.		1-½ ton Quad Truck	Do. (2-½ ton Tractor & Reel transported by 3-ton Quad truck and 4-ton Trailer).
155 mm. Gun S. P. Mount	S. P. Mount	3-½ ton Tractor Caisson.	3-½ ton Tractor Caisson & 3-ton Quad Truck	3-ton Quad Truck	Do.

ly carried, with artillery organizations including ammunition trains to permit the attached repair facilities to function properly.

(d) That responsibility for the repair of all motor equipment within artillery organizations be definitely assigned to the Ordnance Department.

(e) That adequate repair facilities as indicated as in the following table be provided to assure the proper care, repair, and maintenance of both motor and gun material.

Weapon	Battery	Battalion, normally with regimental supply company.	Brigade
75 mm. gun..........	1 light repair truck	1 Art. repair truck	
Light field howitzer....		1 Supply Load D.	Mobile Ord. Repair Shop.
4.7" gun............		1 Supply Load B.	
155 mm. howitzer			
8" howitzer...........	1 light repair truck		1 heavy artillery mobile repair shop (2 sections).
155 mm. gun.........	1 artillery repair truck		
194 mm. gun.........	1 Supply Load D.		
9.2" howitzer.........	1 Supply Load B.		
240 mm. howitzer			
5" seacoast			
6" seacoast converted.			

Ammunition Supply

Unit.	Repair Facilities.
Each Ammunition Truck Company,	1 light Repair Truck
Each 2 Ammunition Truck Companies,	1 Arty. Repair Truck 1 Supply, Load D. 1 Supply, Load B.

(f) That no motor transport be definitely approved for artillery use without a thorough test by artillery organizations.

(g) Eliminating present artillery supply truck body, replacing it with repair body using suitable chest, cabinets, etc.

(h) That the vehicles and repair facilities supplied in time of peace be of the types contemplated for war use.

(i) That there be manufactured immediately 150 Ordnance 3 ton model 1918 four wheel drive, two wheel steer, truck chassis, approved as standard for use in the army by board appointed by Par. 30, S. O. No. 91, W. D., 1918, to be used in motorizing one regiment of 155 mm. howitzers.

(j) Improvement in design and construction of caterpillar treads.

(k) Lowering unit ground pressure of artillery tractors.

(l) Improvement in application of grousers on artillery tractors.

(m) Noiseless exhaust of engine and production of a silent tractor.

(n) The water-proofing of artillery tractor engine to permit them to run submerged for short periods.

(o) A simple form of coupling or attachment to enable guns, tractors, trucks, etc., to be hitched in tandem for towing purposes.

As amended by minority report: WILLIAM I. WESTERVELT
Brigadier General, U. S. Army.

As amended by minority report: ROBERT E. CALLAN
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Lieut. Colonel, Ordnance Department.

As amended by minority report: WALTER P. BOATWRIGHT
Lieut. Colonel, Coast Artillery Corps.

MINORITY REPORT
of
Board of Officers
Appointed by Par. 142, Special Orders No. 2890
War Department 1918

SUBJECT—A study of the armament, calibers, and types of matériel, kinds and proportion of ammunition, and methods of transport of the artillery to be assigned to a field army.

Washington D. C.,
May 5, 1919.

Although it has been the endeavor of the board to keep as free as possible from questions of organization in its discussion of types, the report shows that this could not be done entirely. Types of artillery are dependent on missions to be performed and missions are interwoven with organizations. A reading of paragraphs 11, 12, and 13 might lead to the impression that a field army should include organic army artillery and that a reserve of artillery for reinforcement and special missions should be organized as a thing apart from the organic army artillery.

This does not bring out the views of the minority on one of the most important artillery developments of the European War. The inadvisability of forming organic army artillery has been evidenced on all sides. The opinion of our higher artillery officers in France was opposed to organic army artillery; in fact, no expression of any views favoring such an idea were heard in any of the conferences which the board had in Europe. To go further, considering the organization of European Armies and the opinions of many of our own officers, organic corps artillery is of questionable value. While the army artillery of our First Army was organic and without the reserve principle, except latterly for railroad artillery, the consensus of opinion of those officers who were immediately connected with the Army artillery, as a result of the experience, is opposed to organic army artillery and is in favor of an Artillery Reserve.

The views of the minority of the Board on this whole subject are in brief as follows:

In addition to the assignment of division and corps artillery there must be additional artillery available; there must be a surplus of division and corps types, properly transported, for strategic reinforcement of divisions and corps during such times as the allotment to such units may be insufficient, and also for replacement of disabled units of these types; there must be heavier guns and howitzers for the missions of interdiction, neutralization, and destruction which require greater power and range, or either, than the capabilities of the normal corps or medium field types; there must be artillery of special purpose—trench artillery, pack artillery, anti-aircraft artillery, and super-guns and howitzers. Whether there be one or more field armies this additional artillery should constitute the Artillery Reserve. It should be a complete organization, with proper staff and all the necessary facilities for organizing, equiping, and training artillery units as well as for the repair and replacement of units that have been used up in combat. The High Command should assign a certain amount of this artillery to the army or armies as the necessities of the general situations demand, and as the High Command views the relative importance of these situations; such as assignment to any particular army constitutes the Army Artillery

From the assignment made, the Chief of Artillery of an army is prepared to assign to divisions and corps, such units as the general artillery plan demands; and with such super-guns and howitzers as he may have, he is prepared to undertake, through his own staff, missions of interdiction and destruction which fall beyond the corps artillery's activity or cover zones of adjoining corps and which could, therefore, be better handled for the general good under his immediate orders. When units are used up or are no longer needed, or the plans of the High Command demand a rearrangement of the reserve artillery, these army units should be sent to the Artillery Reserve for repair, re-equipment, replacement, and general refreshing, or to some other theater of action, as the case may be. First of all, this method permits the most economical use of artillery and facilitates upkeep and replacement; and second, it relieves an army from the burden of unnecessary artillery and of much of the large administration, supply, and repair problems that such units involve.

Under the foregoing the Artillery Reserve should contain properly organized and trained units of the following:

Trench motors.
Pack artillery.
Anti-aircraft artillery.
Guns and howitzers of division and corps types.
Guns and howitzers of types heavier than those in corps artillery.
Railroad artillery.

In the composition of large forces there is always the danger of being led astray by the attractions of symmetrical organizations which are not based on the requirements of the battlefield. There is a variety of missions that might be given to any army of the United States; and in the organization of such a force to fit the necessities of the case, there would be greater variations from any normal assignment, in what are known as army troops than in any of the lower sub-divisions of the army. Perhaps in no case would this be more true than in the Army Artillery. In some cases almost no heavy artillery would be needed; in others, the heaviest available might be required. Therefore, whatever may be the plan of military preparedness, the Artillery Reserve, though a thing not considered in our pre-war ideas of organization, should be organized and developed to a high state of efficiency. From the wide range of artillery that such a reserve would contain, the high command, guided by the general mission, could select and assign to an army the tactical units of the appropriate types that should constitute its army artillery.

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◆ ◆ ◆

60" Medium Intensity Mobile Searchlight

Data Furnished by Major Walter C. Ellis, C. A.

The writer has recently had the opportunity of casually inspecting and talking with the designers of a portable searchlight that seems to be likely, on account of its light weight and high speed, to supplant for some uses, the present type of searchlight in use in our various Coast Defenses.

Various times the Artillery Officer who stayed on this side during the war and who had charge of the operation of searchlights will appreciate this outfit when it is adopted by the Coast Artilllery Corps, especially when it can be re-carboned, focused and a perfect crater formed in less than five minutes and when two watchers and an operating crew of three men, including a chauffeur, can get in position, seven miles from their base over reasonably good roads in 35 minutes. This will be of particular interest to any one who has had the experience of quartering and messing small searchlight detachments at remote operating positions. With this unit, rations and quarters for the crew will be in most instances, with their organizations under any, except actual war, conditions.

This searchlight unit consists of a Cadillac chassis, standard thoughout, which has been equipped by the General Electric Company, with a 21 K. W. generator with a hollow armature shaft. The generator is mounted directly beneath the driver's seat, and is brought into operation by a clutch, so that it does not have to be run except when current is required to operate the light.

The hollow armature shaft is fitted over the main driving shaft of the car and the generator, equipped with governor, to prevent racing when load is thrown on, is regidly suspended from the main frame by cast steel brackets, directly in rear of the main clutch.

The rating of the generator is based on a schedule of fifteen minutes on, and five minutes off, but the writer has seen it deliver 180 amperes with 72 volts across the arc thru 300 feet of 1/0 duplex cable for periods of over 45 minutes without overheating. Voltage across the arc is regulated by the field rheostat and no resistance is used in the line. The unit carries 300 feet of duplex cable mounted on a suitable reel equipped with collector rings and the distribution panel is mounted above the running board on the left side of the steering wheel.

The searchlight, mounted on a light, especially designed Ford truck using 30x3 pneumatic tires, is run up, when not in use, on the Cadillac chassis. Light removable channel iron rails are employed for this purpose and each rail may be put in position to mount or dismount the reflector truck, by one man.

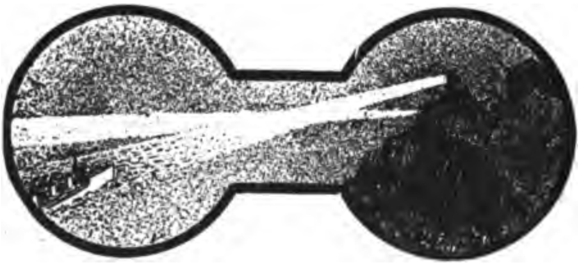
Under what may be termed a "false floor" of the main truck are three horizontal containers, two of which are for lamp mechanism and the third for carbons and miscellaneous supplies.

The lamp mechanisms are simple and easy to operate. They are designed so that an eccentric motion of the negative electrode may be had from a hand wheel thereby enabling the operator to hold a perfect crater at all times, with the aid of a finder.

Another prominent feature of the mechanism is a cylindrical shutter which the operator may close almost instantly without leaving the feed screws. This shutter encloses the arc and prevents any rays therefrom reaching the reflector.

The searchlight is of the "dishpan" type, so that it is necessary to cut away a circular part of the centre of the reflector to adapt it to the lamp mechanism. The searchlight may be traversed through 360°, elevated to 90°, and operates perfectly in a driving rain.

The unit weighs 9000 lbs., complete, and goes over the road at from 40 to 50 miles per hour.



BOOK REVIEWS

The World Peril. New Jersey. Princeton University Press. 5¼" x 7¾". 245 pp. Price, $1.00.

This little volume was published in October, 1917, and is made up of an introduction and seven chapters written by the President and members of the Faculty of Princeton University.

The war is over, and many people in America who have had more or less to do with the Germans in this war fear that the German nation will not be sufficiently punished in the peace conference. This book is not a tirade against Germany, yet it does set forth in most forceful terms many of the political crimes that Germany has committed and points out many of the things she undoubtedly intended to do had she been victorious. Reading this while the peace conference is in session, the question constantly arose will this incident, circumstance or condition brought out in this volume be considered by the peace commissioners and will Germany be brought to account for it?

The first chapter written by Dr. Henry Van Dyke sets forth in wonderfully good language why the conscience of the United States may be perfectly clear as to our having entered the war.

The second chapter indicates the necessity for Germany's defeat in order to make the world safe for democracy. Its author states: "Our foe, the foe of the world, is Prussian military autocracy, and this alone must be destroyed. The world must be made safe for democracy *by* democracy."

Chapter three very clearly brings out the necessity for the punishment of Germany for her violations of international law. The author of this chapter states: "Hence though we entered the war in behalf of our offended rights, we fight in it in behalf of the law and order of the world. A nation which applauds such crimes as the sinking of the Lusitania has lost all sense of responsibility as a member of the family of nations; a nation which thinks and acts by the madcap logic of "World Dominion or Downfall" is a perpetual menace to the peace of the world."

The chapter on "The Balance of Power" very forcefully brings out that a German victory would very effectively throw out the balance of power in Europe, and that after a short breathing spell Germany would be in position to throw out of balance all of the rest of the world.

The chapter entitled "The World Peril and the two Americas," besides indicating the German danger in Latin America, sets forth in a most interesting and forceful manner the relations of the United States with Central and South America. The 84 pages devoted to this subject constitute a most valuable bit of American political history, and, assuming that the opinions and statementsof the author are correct, and I believe they rare, it warns us to go very slowly in dabbling in the affairs of these Latin republics.

The German influence in the Far East is indicated in the sixth chapter and after thoroughly explaining this influence the author in conclusion states:

"It may seem a far field from the present world danger of German arms to the Far East with its seemingly separate problems, its peculiar animosities and alliances. And yet, in an indirect way, it would seem that this situation is a result of the German attempt at world rule. The German danger has withdrawn first Russia, then England, and lastly the United States from the Far East and forced them to concentrate their attention in Europe. And Japan has been left predominant and unchecked in eastern Asia. The German peril is as great in these displacements it effects in the world situation as in its more direct results in Europe and the Near East. And these effects, with their vital importance to us, deserve the serious consideration of all American citizens."

In the seventh chapter, "The World Peril and World Peace," we find:

"But the proofs of the German menace to the world rest not merely on bombastic words, on chauvinistic schemes. The diplomacy of Germany for the last seventeen years has repeatedly revealed the crude reality of her ambitions. It is sufficient to recall the famous telegram of encouragement from the Kaiser to President Kruger, the blusterings of Germany at Tangiers in 1905, again at Agadir in 1911, the loud rattling of the sabre during the Bosnia-Herzegovina crises of 1908-1909 that ended in the humiliation of both Russia and Serbia, the ardent support of Austria against Serbia in 1914 and the insolent ultimatum to Russia which provoked war when Austria had already agreed to a peaceful discussion of the whole Serbian question.

"The foreign policy of Germany during this period was marked by two characteristics: the attempt to acheive her ends by a parade of force; and to embarrass her rivals by sowing dissensions or encouraging disaffection. Militarism could well afford to be content for a while, if it could achieve its ends without actual war. This was an indirect Prussian method of controlling the destinies of other nations.

"Fishing in troubled waters which they themselves have helped to trouble is an art long cultivated by Prussian diplomacy. The Irish disaffection was welcomed and abetted with great joy."

This quotation is indicative of the idea of the entire chapter showing that Germany in the last few years has been a great menace to the world's peace and showing that a complete defeat of the nation and its policies is the only thing that will bring peace to the world without Germany conquering the entire world.

In proving their points concerning Germany's peril to the world, the authors make so many references to historical and political occurrences that the book is made a valuable little history.

Aviation Engines. By John C. Chadwick, Lieut. (J.G.) U.S.N., R.F. New York. E. N. Appleton, Inc. 4¾" x 6". 95 pp. 18 il. Price, $0.75.

This small publication consists principally of three parts: a brief outline of the fundamental principles of operation of internal combustion engines; extracts from descriptive circulars of the manufacturers of the three types of engines discussed; a summary of instructions for the disassembling of the Liberty Motor.

In his efforts to simplify his explanations of fundamentals, the author has "overshot his mark" especially in his explanation of some of the electrical apparatus, making some statements which are misleading.

However, the book probably serves the limited purpose for which it was intended, namely, "to give anyone desiring to operate an aeroplane, a fundamental understanding of engines as used" and intended "simply for instruction of the average individual assuming he knows nothing of a gas engine" and evidently, also of electricity.

The Use of Field Telephones in the Field. By A. G. Gringling, Lieut. 21st Herts Regt. London, Hugh Rees, Ltd., 1916. 4¼" x 6½". 30 pp. 8 il. Price, $0.24.

While the title would lead one to look for a technical discussion of telephones, this little book only discusses briefly the technique of running wires (4 pages) and then describes briefly other methods of transmitting messages (Flag, Heliograph, and Lamp).

A few pages (4 of text and 3 of diagrams) are devoted to running lines in trenches.

The arrangement of the book could be criticized; e.g., (p. 18) a continuation of a paragraph headed "7. Messages. . . . At night moisture often condenses on the lenses obscuring the vision, and they must be frequently wiped. Wires should as often as possible be duplicated . . . "

The Theory of the Rifle and Rifle Shooting. By John W. Hicks, F.R.A.S. London. Charles Griffin & Company, Limited. 1919. 5¼" x 8". 129 pp. 24 il. 5 shillings, net.

This book is an elementary treatise on the scientific principles of the small-arm and its functions. It covers interior and exterior ballistics of the small arm bullet; the causes affecting its flight, air resistance, wind, etc., the use of ballistic tables, calculation of range tables, and the graduation of rifle sights. Reference is made to the results of various experimenters along these lines.

It is an excellent treatise for a beginner in ballistics and gunnery. English letters are used as symbols denoting the various gunnery terms, in place of the customary Greek letters.

Graphical Compass Conversion Chart and Tables. By Major John F. Fairchild, U. S. Army. New York. D. Van Nostrand Company. 4½" x 6¾". 1 Chart & Tables. Price, $0.50.

The conversion tables offer a convenient aid in converting angles in the sexagesimal system, into the centesimal and mils systems; and from the centesimal system into the sexagesimal and mils systems. Another table might well have been added for converting mils into either of the other systems.

The conversion chart appears to have very limited practical advantages.

Non-Technical Chats on Iron and Steel. By LaVerne W. Spring. New York. Frederick A. Stokes Company. 6" x 8¼". 358 pp. Profusely illustrated. Price, $2.50.

This book is a very interesting description of the manufacture of iron and steel, and explains in very simple and non-technical language, the various steps in the processes employed. Its purpose is to describe briefly the treatment of the ore, the production of the iron and its manipulation. The various modifications of this material, the malleable irons, the steels, the alloys, are not only clearly defined, but the processes used in their production explained in an interesting manner.

The text is illustrated by numerous microphotographs showing the structure of the various forms of the materials, and the hardening and tempering processes are not overlooked.

The book, taken as a whole, should appeal to anyone who has observed the universal employment of this indispensable material. The complete elimination of technicalities has been accomplished without destroying this book as a source of valuable and interesting information.

Principles of Radio-Telegraphy. By C. M. Jansky. New York. McGraw-Hill Book Company, 6¼" x 9¼". 242 pp. 179 il. Price, $2.00.

This book is all that the title implies. Professor Jansky is well known in the electrical engineering world, and, being a very able writer, has given a maximum of information with a minimum of words. The book has been written so that it will appeal to the student of limited mathematical education. Lacking some knowledge of geometry and trigonometry, a student cannot expect to obtain a clear idea of alternating and high frequency currents, but this book is so well illustrated with diagrams and problems that one who has only a good working knowledge of arithmetic should have little difficulty in mastering the principles of wireless telegraphy. This book will prove a valuable addition to the library of any electrical student.

Fire Problems. (Third Impression). By Major General T. D. Pilcher. C. B. London. Hugh Rees, Ltd. 4¼" x 6¾". 80 pp. 10 il, Price, $0.37.

This little volume gives a series of typical problems used in training British infantry and cavalry units from a brigade to a squad, in the tactical application of musketry training. They are simple in scope and, as the author indicates, have "the object of filling up the gap which is sometimes apt to occur in * * * training at the place where range firing ends and tactics begin."

The method of presentation is to state the problem, usually with the aid of a sketch map, and then follow with a critique of actual solutions of the problem. This book is particularly for infantry, but the instructional method outlined, as well as the presentation of the method should be of significance to artillery officers of all grades.

American Labor and the War. By Samuel Gompers. New York, Geo. H. Doran Company. 5¾" x 8¼". 1919. 377 pp. Price, $1.75.

It is hardly necessary to state that the author is the President of the American Federation of Labor. This book is a compilation of some twenty-four speeches made by Mr. Gompers at different times within the past five years. All deal, to a greater or less extent, with the attitude of Labor toward the war, both before, and after our entrance into the conflict.

An appendix gives the "pronouncements" of the yearly conventions of the American Federation of Labor from 1914 to 1918.

The speaker's wide knowledge of conditions, and his clear, forceful English, make the book a convincing exposition of the support given by Labor, as a whole, to the administration during the war. It is a rather unusual, and very refreshing, point, to note that these speeches have been printed without the usual interpolations of [Laughter], [Applause], [Prolonged Applause], etc. (Congressional Record please copy).

Gas and Flame in Modern Warfare. By Major S. J. M. Auld, Royal Berkshire Regiment. New York, Geo. H. Doran Company, 1918. 5¼" x 7¾". 201 pp. Frontispiece. Price, $1.35.

The author was a chemist before the war, and volunteered as a "territorial." After the first use of gas at Ypres by the Germans, he was taken into the gas service, and was later appointed Chief Gas Officer of Sir Julian Byng's Army.

He visited America as a Gas expert, on detail from the British Government, and has assisted our Gas Service in organization and research work, and in production of gas, and has lectured extensively.

Of the ten chapters into which this book is divided, nine are devoted to a semi-technical discussion of the various classes of toxic and poisonous gases, and their uses, while Chapter ten deals with flame throwers.

The book is of great interest, both from a historical and a technical point of view, and appeals both to those who have, thru stern necessity, perfected themselves in the "five-second masking," and those who have never heard the howl of a Strombos horn, or the blat of a Klaxon.

Organization. (*How Armies are Formed for War.*) By Col. Hubert Foster R. E. London. Hugh Rees, Ltd. 5¾" x 8½". 266 pp. Price $0.85.

This book covers a considerable range of subjects connected with Organization. Part I presents the principles and practice of war organization of the present day, including the functions of command, the characteristics of the various arms and a discussion of staff work. Part II is devoted specifically to British war organization, while part III describes briefly the composition of war organization in the principal countries foreign to Great Britain. A particularly valuable part of the book is the historical development of Organization, presented in Part IV. The concluding Part V treats of Military Command, particularly from the standpoints of psychology and leadership.

Training Soldiers for War. By Capt. J. F. C. Fuller, London. Hugh Rees, Ltd. 4¼" x 6¾". 123 pp. Price, $0.49.

This is an earnest discussion of the factors and priniciples underlying training, such as morale, psychology of individuals and of crowds, habit, suggestion, doctrine, confidence, discipline and initiative. Based upon the discussion of principles are formulated concise and practical suggestions concerning the details of training, including barrack discipline, drill, lectures, musketry, field training, physical training, and by no means least, recreations.

Military Landscape Sketching and Target Indication. By W. G. Newton, London. Hugh Rees, Ltd. 7¼" x 4¾". 45pp. Profusely illustrated. Price, $0.37.

A manual of intensive instruction in the subject, which is approached from a different standpoint from nearly all American texts. The author recognizes three methods of analysis of any terrain to be sketched (1) Separation of Planes, (2) Encircling or Framing-In, and (3) Division of a Whole into Parts. The methods set forth are developed from a combination of these three conceptions. Important hints are given in sketching with glasses and the periscope. Perhaps the most useful feature of the book is the series of practical sketches constituting the illustrations.

Military Map-Reading Simply Explained. By W. P. Lynam. London. Hugh Rees, Ltd. 5" x 7". 104 pp. Profusely illustrated, 1 map. Price, $0.49.

Of the many books on this subject, this is certainly one of the best we have seen. Its excellence lies first, in the illustrations, which are admirable, and second, in the fact that the presentation is so clear as to make the book amply live up to its title.

What to Observe and How to Report It. By Col. Sir Lonsdale Hale, London. Hugh Rees, Ltd. 4¾" x 5¼". 69 pp. Profusely illustrated. Price, $0.18.

This little book is intended as a guide for the training of scouts and patrols, perhaps particularly of cavalry. The treatment is concise and pithy, covering the technique of local reconnaisance, sketches, and messages, and reports. The terminology used is that current in the British Army, but the methods outlined closely parallel our Own Field Service Regulations. Tables of weights and measures, and conventional map signs add to the little book's value.

The Solution of Tactical Problems. 11th Edition. London, Hugh Rees, Ltd. 5¾" x 8½". 277 pp. 7 diagrams. Price, $1.22.

This work has evidently found a ready acceptance in England, as it has run through eleven editions. It may be sufficiently descriptive of the character of the volume to say that it has somewhat the scope for the British service that the well-known "Technique of Modern Tactics" of Bond and McDonough has for the American service. The book should prove particularly valuable to two classes of American readers, those who want to compare British terminology and technique with our own, and those who may make a comparative study of British practice before the war, (which this book represents) with their own developments during the war.

The Naval Artificer's Manual. By (T) McCall Pati, U. S. N. Maryland, U. S. Naval Institute. 5½" x 8". 797 pp. 126 il. Price $2.00.

This excellent work is based on the Naval Artificer's hand book 1914 which was prepared primarily for use as a handbook and textbook for Deck Artificers in the extension of education for enlisted men in the United States Navy. In its present revised form it is replete with information and data of the greatest value to students of the mechanical trades, Nautical Students, Shipbuilders, Boat Owners, and as a reference book for Mechanics, and Deck Officers on all types of modern ships. The scope of the book covers a wide range including elementary arithmetic, rules and tables of weights, measures, etc., weights and strengths of materials, rules for inspection of and description of all kinds of lumber used in the Navy; descriptions of drainage, sanitary and ventilation systems, steering appliances including telemotors, oxy-acetylene welding, etc.; standard formulae for mixing all kinds of paints on iron and steel vessels. Examination questions pertaining to the different trades of Deck Artificers, glossary of technical and Nautical definitions, etc. A well arranged and most valuable text and reference book.

Handy Book for the Enlisted Men in the Engineering Department U. S. Navy. By B. R. Ware, Jr. Revised and enlarged by A. H. Rice, Jr. Maryland U. S. Naval Institute. 4" x 6". 278 pp. 119 il. Price $0.50.

As indicated by its title, this book was prepared primarily as a practical aid for enlisted men in the Engineering Department of the United States Navy. While it does not go too deeply into Marine Engineering, yet it covers thoroughly the important principles, and is written "so that you can understand it." The illustrations and diagrams are copious, clear cut, and well annotated.

A valuable reference book for Marine Engineering students, and officers in the Commercial, as well as the Government Marine Service.

A History Of The Great War. The British Campaign In France And Flanders. 1914. By A. Conan Doyle. New York, Geo. H. Doran Co. 5¾" x 8¾". 349 pp. Price, $2.00.

As an historical work this book will appeal most strongly to the friends and relatives of the men who gave their lives to the Great Cause.

The first two chapters which Mr. Doyle calls "political Chapters," and for which he speaks rather apologetically in his preface, are exceptionally interesting and are written in a spirit of great fairness to the German agressors.

Chapter Eight, "The First Battle of Ypres" takes us back to the days of awful tension in 1914 when Britain's thin line was fighting so dauntlessly, when, as Mr. Doyle says," they had given their all, almost their humanity to save Britain."

The book closes with the promise of two more volumes.

The printing of the Chapter number and title in the margin will be very helpful in the use of the book for reference work.

Higher Arithmetic. By George Wentworth and David Eugene Smith. Ginn and Company. c1919. 250 pp. 7¾" x 5¼". Price, $1.00.

Quoting from the preface: "This work is intended for teachers in normal schools and for students in high schools...the latter because they need a thorough review of the principles. of arithmetic before they enter upon their life work. ...Special attention is given to the principles of the subject rather than to that mechanical drill which necessarily characterizes the instruction in the lower grades."

This book fulfills, in an excellent manner, the promises made in the preface. It will appeal especially to one who has neglected or partially forgotten the arithmetic of his high-school years, and the statements and explanations are so clearly stated that no necessity is found for the searching for some forgotten rule. In many places simplified methods are introduced, as well as simple checks and methods of proving results.

The paper, typography, and general make-up of the book are excellent. Small tables of square roots and logarithms are included.

The Elements of Astronomy. By Charles A. Young, Ph. D., L.L.D. Boston. Ginn & Company. 5¼"x7½". 507 pp. Profusely il. 4 Maps. Price, $2.00.

This is an excellent elementary treatise on astronomy, written in an easy style, and requiring a knowledge of mathematics no higher than algebra and geometry. The text is replete with excellent diagrams and illustrations. For the student desiring to go further into the subject, there is an exhaustive appendix supplemented by an excellent uranography. The "Synopsis for Review and Examination" will be found useful to both teachers and pupils.

Induction Coils in Theory and Practice. By Prof. F. E. Austin, E. E. New Hampshire. 5½"x8½". 64 pp. 45 il. Price, $1.00

This is a small book designed to explain the fundamental principles of the induction coil. It presents the theory of this type of apparatus in a very brief and simple manner, being written for the student with limited education particularly along electrical lines.

There are numerous sketches and diagrams—well chosen, but many displaying crude draughtsmanship.

Considering the book as a whole, it is a good elementary text, the author having succeeded in imparting much valuable information in spite of the brevity of the treatment of the subject. Its greatest drawback is the fine print, the small type imposing a serious strain upon the careful reader.

Notes on Field Artillery (for officers of all arms). By Oliver L. Spaulding, Jr., Colonel, 8th Field Artillery, U. S. Army, Ft. Sill, Okla.; 4th Edition, Kansas. U. S. Cavalry Asso. 5¾"x8¾", 244 pages, 21 il. Price, $1.50.

The purpose of this book is to familiarize officers of other branches of the service with the workings of the Field Artillery. It appears to have been written directly to the Infantry officer. It is well written in logical order and in simple language. Due to the many changes caused by the recent war, the book is hardly up-to-date. Though of doubtful value to any artilleryman (as it contains little that the youngest artilleryman does not know) it should, however, prove to be a good liaison volume for Infantry and Cavalry officers. The examples used to illustrate the development of artillery are very interesting and have been well chosen. The author realizes the modern change from maneuver to position warfare and gives a very good chapter on this subject.

The Web. By Emerson Hough. Reilly & Lee. 5½"x8". 511 pp. Price, $2.00.

This history of the work of the American Protective League will come as a surprise to a very large number of patriotic Americans who knew nothing of the existence of such a league. The book should be placed in the public schools throughout the country in order that the youth of our land may have the patriotic inspiration which its pages affords; that they may learn first hand, duty to one's country and obedience to its laws. Had it not been for the high purpose of the A.P.L. anarchy, riot, incendiarism, evasion of the draft law, and endless crimes would have wasted our great efforts in the war. The book is a marvelous revelation of truths we should all know.

Abraham Lincoln as a Man of Letters. By Luther Emerson Robinson, M. A. Reilly & Britton. 5½"x7½". 342 pp. Price, $1.50 net.

The growth and development of the literary life of Lincoln is remarkably well set forth by Professor Robinson. He shows us with a very keen and delicate touch how the great experiences of Lincoln's life reacted on his written words until finally, we have from him at least two of the master pieces of literature. This new Lincoln book should find a large field for itself.

An Illustrated History of the 71st Artillery (*C.A.C.*). Indianapolis, Indiana, Press of Wm. B. Burford, 1919. 192 pp. plates, illustrations. 10¾" x8".

The reviewing of this book is an unusual pleasure, instead of a task. Its make-up is unusually good, the typography excellent, and the many portraits will materially assist in making the book one to be highly prized by every man who has been so fortunate as to be a member of this regiment. The compiling and publishing of such a work furnishes excellent proof of the fine regimental spirit that must have existed in the organization.

The book gives a sketch of the organization of the regiment, and brief articles on its separate parts, each followed by an excellent roster, showing name, rank, occupation, and address.

A plentiful supply of cartoons and photographs of different stations, and of varied occupations of the men add greatly to its value.

It is hoped that this will prove to be the forerunner of many other regimental histories, which will not only keep green the memories of "those happy days, those scrappy days, those days in dear old France" but will be prized more and more in succeeding years, and be handed down to the next generation to show "what Daddy did in the war."

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Builder and Woodworker, The, ...
Cabinet Making and Upholstry, ...
Canadian War of 1812, The . . . . C. B. Lucas.
Decisive Battles Since Waterloo, the Most Important Military Events from 1815-1887, ... T. W. Knox.

Elementary English Composition,	Fred Newton Scott.
Fall of Constantinople, Being the Story of the Fourth Crusade, The,	Sir Edwin Pears.
Fall of Napoleon, The,	Oscar Browning.
Harmony and Instrumentation; the Principles of Harmony,	Oscar Coon.
History of the War in France in Belgium in 1815: Containing Minute Details of the Battles of Quartrebras, Ligny, Wavre, and Waterloo,	William Siborne.
Military Sketching and Map Reading,	Loren C. Grieves.
Napoleon and the Archduke Charles: A History of the Franco-Austrian Campaign in the Valley of the Danube in 1809,	F. L. Petre.
Napoleon's Marshals	R. P. Dunn-Pattison.
Port Arthur, the Siege and Capitulation	Ashmead, Bartlett, Ellis.
Practical Band Arranger: A Systematic Guide for Through Self-Instruction, The	Louis P. Laurendeau.
Technical Mechanics, Statics and Dynamics	Edward Rose Maurer.
War in the Far East, 1904-1905, The	C. A. Repington.

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American Ephemeris and Nautical Almanac, The	
Arithmetic of the Steam Boiler	C. J. Mason.
A Textbook of General Astronomy for Colleges and Scientific Schools	C. A. Young.
Automatic Telephony: A Comprehensive Treatise on Automatic and Semi-Automatic Systems.	A. B. Smith.
Automobile Blue Book, Volume Three, 1919	
Bluejackets Manual, The	McLean, Ridley.
Boilers	H. E. Collins.
British Navy in Battle, The	Sir. Arthur H. Pollen.
Computation Rules and Logarithms with Tables and Other Useful Functions	Silas W. Holman.
Constitutional Law, A Text Book of	E. G. Davis.
Deck and Boat Book, The,	
Elements of Hydrographic Surveying	G. W. Logan.
Elements of Law, The	George B. Davis.
Engineer Field Notes	
Engine-Room Chemistry	Gill, Augustus, Herman.
Erecting Work	Hubert E. Collins.
Essentials of Alternating Currents	W. H. Timbie and H. H. Higbie.
Essentials of Geography	Albert P. Brigham.
High School Arithmetic, A	H. A. Wentworth.
Instructor's Guide, Mechanics Section, Company Mechanics Course	Motor Transport Corps.
Instructor's Guide, Motor Car Section, Chauffeurs Course	Motor Transport Corps.
Instructor's Guide, Motor Truck Section, Truckmasters Course	Motor Transport Corps.

Instructor's Guide, Motor Cycle Section, Drivers Course	Motor Transport Corps.
Instructor's Guide, Motor Truck Section, Drivers Course	Motor Transport Corps.
Joint Wiping and Lead Work: A Series of Practical Hints on the Preparation of Lead Pipe and Connections and the Wiping of Joints in Various Positions	William Hutton.
Lectures on Modern Seamanship	
Mechanical Engineers Handbook	L. S. Marks.
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Modern Seamanship	Austin Melvin Knight.
Navigating the Ship	E. G. Draper.
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Steam Engines	E. M. Shealy.
Steam Turbines	H. E. Collins.
Text Book of Physics, A	G. A. Wentworth.
Topographic, Trigonometric and Geodetic Surveying, Including Geographic, Exploratory, and Military Mapping	H. M. Wilson.

Journal of the United States Artillery

Vol. 51 No. 2 AUGUST, 1919 Whole No. 156

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Spotting for Coast Artillery

Equations of Differential Variations in Exterior Ballistics

The Concluding Installment of

Coast Defenses Constructed by the Germans on the Belgian Coast

and

the Second Article of a Series of Three on

High Burst Ranging

JOURNAL OF THE UNITED STATES ARTILLERY

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JOURNAL OF THE UNITED STATES ARTILLERY

Published under supervision of the Coast Artillery Training Center Staff, by direction of the Chief of Coast Artillery.

12 numbers per year; volumes begin January and July. Issued on 15th day of each month.

Entered at the Post Office at Fortress Monroe, Va., as second class matter.

Subscription price, per annum:

Domestic	$3.00
Canada	3.25
Countries in the postal union	3.50
Single numbers	0.30

All subscriptions payable in advance.

Subscriptions may be entered to begin with any desired issue of the Journal. It is suggested that those who have not the numbers beginning with January, 1919, will find it desirable to begin with that issue, as all the numbers from there on are filled with especially live, important matter.

Make checks, drafts, and postal orders payable to JOURNAL U. S. ARTILLERY.

Remittances, articles intended for publication, and communications relating to the management should be addressed JOURNAL U. S. ARTILLERY, Fort Monroe, Virginia.

It is earnestly requested that prompt information be given of changes of address, or failure to receive the JOURNAL. Both old and new addresses should be given.

COLONEL R. R. WELSHIMER, C. A.
Manager and Editor
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London Agents:
B. F. Stevens and Brown, 4 Trafalgar Square

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1919

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(b) Award will be made by a committee of award, consisting of three persons, to be nominated by the Coast Artillery Training Center Staff. If no essay submitted seems to the committee worthy of a prize, none will be awarded. Honorable mention may be made of any essay submitted which seems to the committee worthy thereof, but to which a prize is not awarded

(c) All essays entered in competition will become the property of the JOURNAL OF THE UNITED STATES ARTILLERY. These will be published. if approved by the Coast Artillery Training Center Staff.

(d) Copy must be typewritten, with lines double spaced, on one side of the paper only, and must be submitted in triplicate. If illustrations are included, one of the three copies thereof must be in the form of drawings, tracings, or photographs (not blue-prints nor brown-prints).

(e) Copy must contain nothing to indicate its authorship, must be signed with a *nom de plume*, and must be accompanied by a sealed envelope containing this *nom de plume* and the name of the writer. This envelope will remain in the hands of the Editor of the JOURNAL and, after award has been made by the Committee, will be opened in the presence of the Coast Artillery Training Center Staff.

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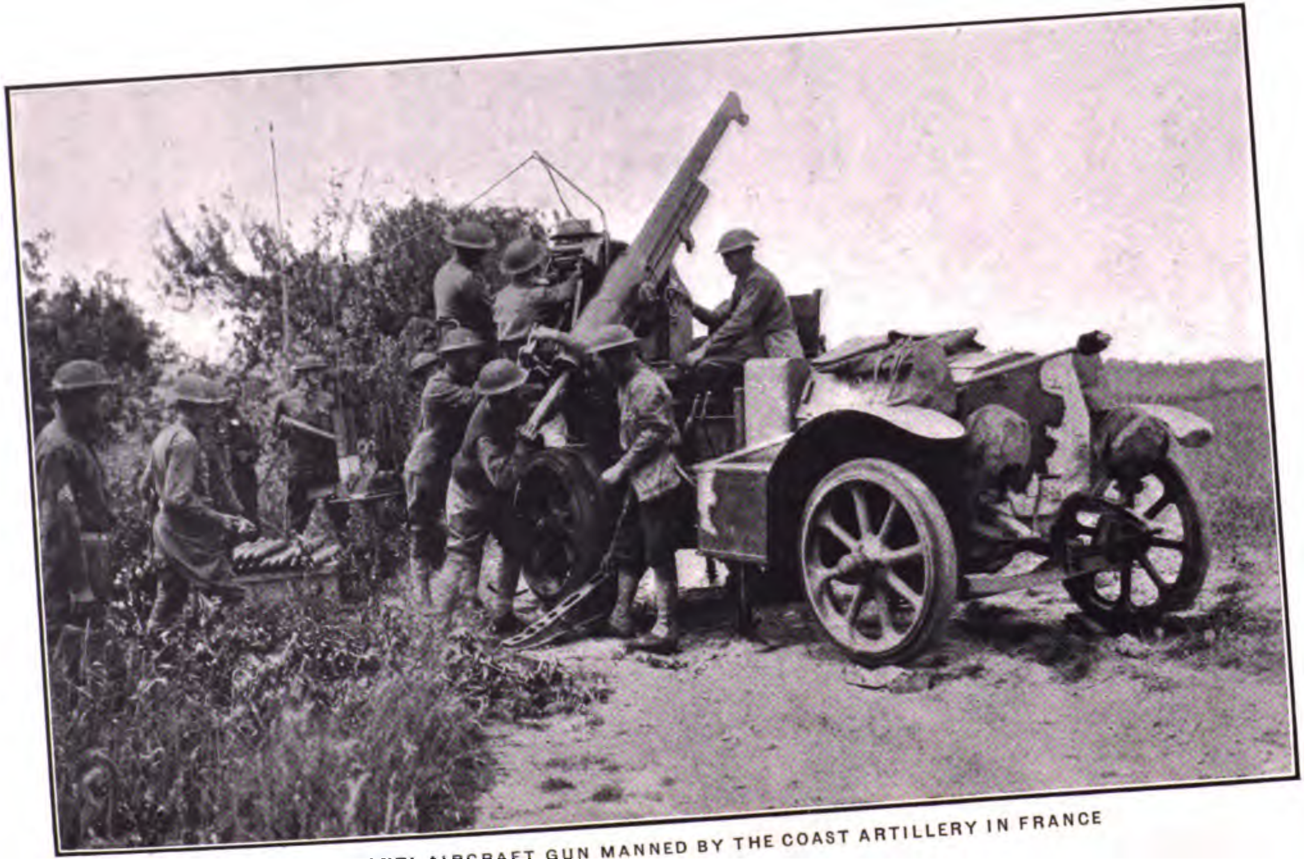


A 75 MM. ANTI-AIRCRAFT GUN MANNED BY THE COAST ARTILLERY IN FRANCE

JOURNAL

OF THE

UNITED STATES ARTILLERY

Vol. 51, No. 2. AUGUST, 1919 Whole No. 156

Spotting For Coast Artillery

By Major C. M. Burlingame, F. A.

Part I.

Justification of Spotting

If absolute perfection could be attained in the manufacture of firing weapons, projectiles, and explosives; and in the construction and use of apparatus for determining conditions affecting firing data, then we might, with a perfect knowledge of these conditions, entirely eliminate the Scylla and Charybdis of sea-coast marksmanship; these being (a) dispersion, and (b) error in placing the center of impact; but, unfortunately, such perfection does not exist, and our already satisfactory knowledge of the laws of dispersion has not by itself enabled us to elimate dispersion. On the contrary, to a certain extent we sometimes take advantage of dispersion to get hits which otherwise would be impossible, as will be shown, but that is only one of the paradoxes of artillery firing, and is never an argument in favor of not reducing dispersion to the minimum attainable.

For instance, because of our inability ever to place accurately our center of impact upon the exact expected location, when employing unobserved fire, dispersion often seems to be an assistance, since without dispersion, to lose one shot would mean losing all of them. However, with the assistance of dispersion, which scatters shots away from the center of impact only to throw some of them in the direction of the target, we do obtain an occasional hit in this class of fire, in spite of our inability to place the center of impact upon the target.

Now, let us consider Charybdis.

Employing observed firing, as we reduce the deviation of the center of impact, it becomes to our advantage to reduce at the same time our dispersion, since the less the dispersion, the greater the probability of hitting is known to be in the vicinity of the center of impact; and whatever degree of dispersion we may have, the probability of hitting becomes much greater as the distance lessens from the target to the center of impact.

The above statements are made in a more concise form in the War Department Manual "Musketry," paragraph 104, which states "that the advantage of small dispersions decreases with the range *when the correct elevation is not used,*" and the converse "that there is a *great advantage in small dispersion when the range is exactly known.*"

It is obviously to our advantage, since we cannot bring target and center of impact together by predetermined corrections, to do so by means of corrections based upon proper observation of fire, and upon exact laws of control, using accurate observation as a basis. The practicability of such control is admitted in the case of small arm firing, and is the basis of the Field Artillery system of firing. In Coast Artillery methods, however, spotting has never in the past been considered as a necessary aid to adjustment of fire. It has been undeveloped, and consequently it has, in the past, been looked upon as a doubtful auxiliary, not to be relied upon, and to be employed with considerable caution, and then only under the most favorable circumstances.

We will discuss some of the influences which have retarded the development and use of spotting by the Coast Artillery.

First:-A prevailing belief that in action no battery will be able to pick out its own splashes.

This could be true only in the event that all batteries were firing at the same time in an indescribable chaos of lack of direction and control. The very foundation of our system of tactical command is the realization that such confusion must never be allowed to exist; that targets must be assigned by position and by caliber, and that the tactical commanders must never lose their grip on the situation. Now, we know that the splashes of different calibers are readily distinguishable when falling in proximity. Splashes from different batteries of the same caliber are readily distinguished from one another when projectiles from different quarters of the compass strike near together. These facts are conditions which should be considered by tactical commanders in assigning targets. Moreover, the Infantry and the Field Artillery recognize the efficacy of a proper distribution of fire, and there is fully as great an occasion for such correct distribution in the Coast Artillery.

The first objection is thus seen to be based entirely upon incorrect assumptions.

Second:-A prevailing belief that any correction based upon a limited number of observed deviations should be futile, in view of the fact that at the ranges employed in Coast Artillery firing, the dispersion is a large and uncertain factor.

Does not dispersion exist in Infantry, and in Field Artillery firing, to practically the same extent in proportion to the ranges used, as it does in Coast Artillery firing? Does this fact prevent adjustment of the center of impact in those classes of fire? And do we not also, even in unobserved Coast Artillery firing, make use of the fact that a center of impact exists? The laws of probability certainly allow the use of the center of impact in observed as well as in unobserved firing.

This objection, then, cannot be sustained.

Third:-The impossibility of definitely keeping the center of impact upon the target, due to the variable displacement of the center of impact as the gun heats and cools, and as other unknown conditions affect the velocity and deflection; has been stated as an objection to observed firing.

The objector fails to see that this variation cannot possibly be overcome in unobserved firing. In observed firing, on the contrary, this variable tendency may be largely overcome by discarding all except the last few shots already fired; as, for example, the last six, or the last three, in determining the correction to be made. The motion of the target itself will enter into this tendency and only the combined effect need be considered.

Fourth:-The fact that the deviations determined by observation are approximate only and never exact.

Can a correction in range be based better upon an approximate knowledge of deviations involved, or as in many attempted corrections in the past, upon the absolute ignorance and guesswork which has accompanied numerous ill-advised attempts to correct shots whose deviation had not been measured or even correctly sensed? And should we be content to shoot away costly ammunition without even attempting to adjust ranges which we know from experience to be probably greatly in error?

Skill develops rapidly with a large amount of practice.

Present methods of spotting are very valuable, but are very far from perfection. We do not even claim that perfection will ever be attained, but constant improvement is being made, and development in methods is progressing through a better acquaintance with their principles. In previous observation inaccuracy has resulted partly from the crudeness of the methods employed, but more largely from the crudeness of the apparatus used. However, the lack of suitable apparatus which has prevailed in the past is not nearly so likely to hamper us in the future.

Fifth:-It has been contended that control by observation is not essential to accurate firing by Coast Artillery.

The Infantry and the Field Artillery have found it essential. For the Coast Artillery to cast aside without a sufficient trial this asset of proven value and assistance would be foolhardy.

Sixth:-The difficulty of computing the deviation in time to make use of the correction before the next shot is fired.

A number of methods of spotting have been employed in Coast Artillery firing; and nearly all of these have required only a few seconds for combined observation and computation of the deviation. What more can reasonably be wished for? Besides, are not a few shots that are well adjusted by observed control, worth fifty of the kind which depends upon dispersion for their effectiveness?

Seventh:-No one single method of spotting used in the past has been applicable to all batteries, or even to the same battery for different firings.

Can these facts be urged as an objection to control of fire by observation? No, for although nearly all batteries differ in their elevation, the length and position of their base lines, their effective ranges, the extent and shape of their fields of fire, the configuration of their shore line and intermediate terrain, the direction of their seaward approaches, and many other conditions of fire; the usefulness of each tried method of spotting, when applied to a suitable set of conditions has been amply demonstrated.

Certain combinations of not more than two suitable methods of spotting will usually be sufficient to meet all circumstances which exist or can be expected to arise during the firing from a single battery, or during firing from neighboring batteries which are compelled to make use of the same spotting apparatus. Sometimes circumstances are equally favorable to each of two different methods. In the latter case one method may be used to support and check the other, or either one may be discarded in favor of the other, a single practicable method being preferable to the more complex scheme involved in the use of two methods.

Part II.

A. Reference to Previous Discussion

Much progress has been made in the observation of fire in land warfare by both light and heavy artillery. Some of the instruction pamplets, documents, regulations, and text books contain much interesting data on this subject, and some of the principles which they elucidate are applicable also to Coast Artillery. However, a direct history of the progress of Spotting for Coast Artillery may be gained only from the unprinted experience of those in the service, and an occasional contribution appearing in our Journal.

These latter comprise to date about a dozen articles, most of them appearing in the last two years. The following list contains practically all of them:

January-February 1911-"Range Corrections from Observation of Fire," by "Observer."

July-August 1913. Articles by H. T. Clark and L. H. Campbell.

Vol. XLVI, p. 333. "A Horizontal Base Spotting Board," by L. A. McLaughlin.

Vol. XLVII, p. 199. "Observation of Fire," by Cecil G. Young.

Vol. XLVIII, p. 170. "Adjustment of Mortar Fire Based on Instrumental Observation," by C. W. Waller.

Vol. XLIX, p. 205. "Spotting Board," by G. Ralph Myer.

Vol. L, No. 3, p. 328, May 1919, "Mechanical Spotting Device," by the author.

B. Figures and Legend

LETTERS

Splash	S
Target	T
Battery	B
Spotting Station	B′
Secondary Spotting Station	B″
Observer's Angular Displacement	BTB′
Secondary Observer's Angular Displacement	BTB″
Observer's Angular Displacement (In Degrees)	t′
Secondary Angular Displacement (In Degrees)	t″
Sum of Bilateral Angular Displacements	t
Lateral Deviation	DS
Lateral Deviation (In Yards)	d
Longitudinal Deviation	TD
Longitudinal Deviation (In Yards)	r
Absolute Deviation	TS

Spotting Line	B'T
Spotting Line Component of Absolute Deviation	PS
Spotting Line Component of TS (In Yards)	r'
Spotting Lateral Coordinate	TP
Spotting Lateral Coordinate (In Yards)	d'

SYMBOLS

+	Center of Impact
o	Splash
×	Expected Splash
△	Target

FIGURES

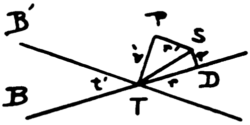


Fig. 1

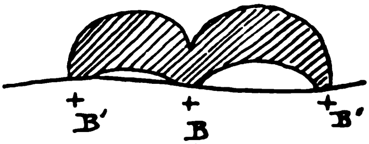
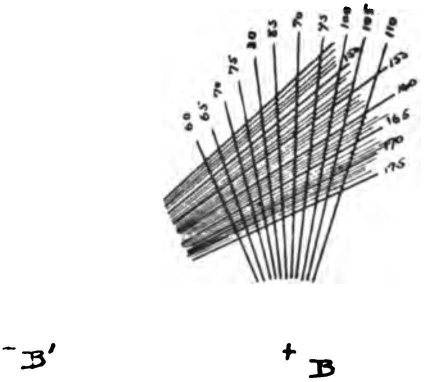


Fig. 2



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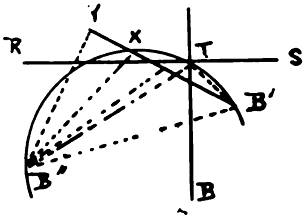

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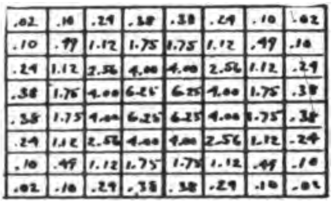
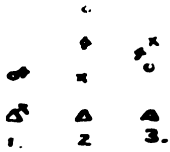


.02	.10	.29	.38	.38	.29	.10	.02
.10	.49	1.12	1.75	1.75	1.12	.49	.10
.29	1.12	2.56	4.00	4.00	2.56	1.12	.29
.38	1.75	4.00	6.25	6.25	4.00	1.75	.38
.38	1.75	4.00	6.25	6.25	4.00	1.75	.38
.29	1.12	2.56	4.00	4.00	2.56	1.12	.29
.10	.49	1.12	1.75	1.75	1.12	.49	.10
.02	.10	.29	.38	.38	.29	.10	.02

Fig. 5.



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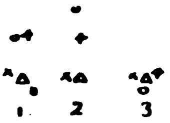
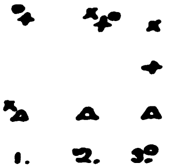


Fig 7



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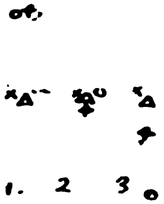

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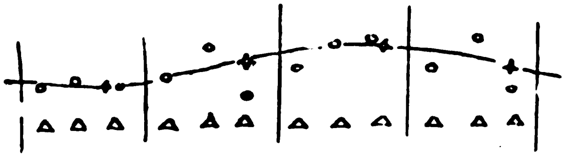

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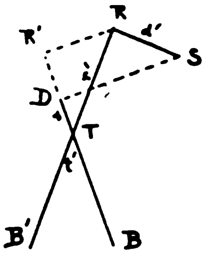

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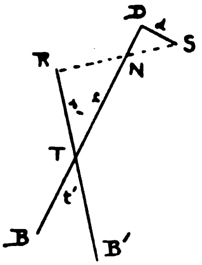
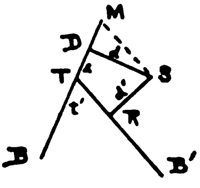


Fig 12.



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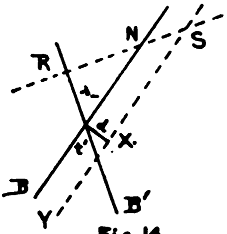

Fig. 14.

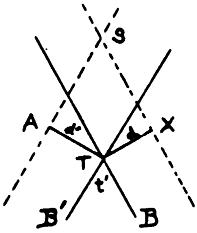

Fig. 15.

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C. Description of Methods in Use

Silhouetting

Splashes which are short are silhouetted against the target. The splashes of those shots which pass through the target or over the target are either hidden by the outlines of the target, or appear wholly or in part above the outline of the target.

This method of spotting can be used successfully by a rapid fire battery to bracket a target which presents a long side to the battery, leaving little chance for a miss in deflection. It cannot be used against a head-on target, or a narrow target whose azimuth is rapidly changing, or against some of the smaller targets that are often used in subcaliber or service practice. Larger caliber batteries may make a limited use of it in action against broadside presentation.

Other objections to use of this method by batteries of large caliber are that good results can be obtained only by an enormous expenditure of ammunition; and that too much time is required for adjustment against moving targets. This is equally true of any other method which fails to determine measurements, giving instead sensings only.

Waterlining

This method is a variation of the method described below under *vertical spotting*, and consists in determining whether the trace of the splash is above or below the straight line which comprises the waterline of the target, prolonged on both sides beyond the target. The method is very unreliable, in that a trace to the right of a target in the left of the field may be above the waterline of the target, and still be considerably short; with opposite contradictions on the left of the target, and similarly but in opposite sense in the right of the field.

It has also many of the same objections that are enumerated below under vertical spotting.

Vertical Spotting

The range to the target and the range to the splash are read from a Depression Position Finder. The spotter algebraically substracts the range to the target from the range to the splash, and communicates the result to the battery Commander.

For a high battery, the spotting station may be at the battery or in the vicinity. With a low battery, the station must be on high ground in the rear of the battery, since this method is not adapted for a spotting station located very far from the line of fire, as will plainly be seen from a few illustrative examples.

In Fig. 1:-TP is drawn perpendicular to B'T. PS is drawn parallel to B'T. DS is drawn perpendicular to BD.

Example I. Suppose DS equals 25 yards, TD equals 100 yards, and t' equals 30 degrees. Then TS will equal the square root of 25^2 plus 100^2, which is equal to 103.0 yards. PTS equals 90 degrees minus (t' plus DTS). Sin DTS equals 25/103.0, equals .24. DTS equals 14 degrees, approximately. PTS equals 90 degrees less (30 degrees plus 14 degrees), equals 46 degrees approximately. r' equals TS sin 46 degrees, equals 103.0 times .72, equals 74 yards.

But r' was the over as measured by the spotter at B', whereas TD is the actual over. The discrepancy is 26 yards. Wider deflections greatly magnify such discrepancies.

Example II. Suppose t' remains unchanged, and a line shot strikes 300 yards beyond the target. Then DS is eliminated, and TS becomes 300 yards. PTS becomes PTD, which is 60 degrees. r' equals TS sin 60 degrees, equals 260 yards.

The discrepancy in this case is 40 yards for the minimum deflection error.

Larger deviations give greatly increased errors. The practicable limiting value of t' for the above method of vertical spotting is very much less than 30 degrees.

Assuming now that we use the method correctly, that is, from a station in immediate vicinity of or in rear of the battery, we still find that there are a number of objections to this method.

1st Objection. The extreme difficulty of accurately waterlining both the target and the center of the splash before there takes place any material change in their relative positions, or in their relative elevations due to the rise and fall of the waves. If the splash is waterlined immediately, its mass hides its own extent in perspective, and the horizontal wire can be placed only by estimation. If the observer waits until the splash has almost subsided, he has to contend with a turbulent, irregularly shaped mass, often 50 yards or more from its nearest to its farthest edge. This foaming mass, if there is any wind or current, has already moved a considerable distance since the moment of impact. If the observer waits longer, there are no reliable traces of the original location of the splash. All of this time there has been the rise and fall of the splash position due to the rise and fall of the swell, varying in moderate weather from four feet above to four feet below the plane of midlevel of the target positions.

To find approximately the affect on the range reading produced by a vertical movement of the target, we must multiply the vertical movement by the cotangent of the angle of depression corrected for curvature. At midrange this multiplier varies from 30 for a very high site to 200 or more for a hundred foot site. An eight foot vertical difference would thus give a horizontal difference of from 80 to 500 yards.

2nd Objection. Even when the readings on target and splash are simultaneous, there may still be, and very often is a difference of their levels due to the fact that either one may be at the crest of a swell while the other, at a distance therefrom, is in the trough between the two swells. The effect is the same as in the first objection.

3rd Objection. The difficulty of accurate reading greatly increases for an inadequate height of site, and also for excessive ranges. This is because the change in position of the horizontal wire becomes so slight that the slight angular motion of the telescope may scarcely overcome the back-lash, thus failing to register the correct difference of elevation. Also, the observer is less able to estimate small changes, and his smallest errors correspond to large horizontal differences.

The errors from the above sources, when combined with those due to the lateral location of the spotting stations, may thus render this method useless for effective adjustment of fire, even independently of the first two objections.

The third objection would be rendered less objectionable by the employment of a special telescope containing a movable, as well as a fixed, horizontal wire with a vertical scale of units convertible into yards by means of a definite factor for each range from a given altitude. Such an instrument could be used from an artificial height impracticable for a Depression Position Finder.

4th Objection. The frequent failure of observers to catch both target and splash within the field of the telescope necessitates a loss of time in finding and waterlining the splash. This would also, of course, throw out many of the readings with a movable wire instrument.

At a service practice with major caliber guns, the fire commander attempted the vertical method of spotting for subsequent comparison with a different method employed by the battery commander. In violation of the principles explained above, the spotting station was located about 3400 to the flank of the battery, and a Lewis, Class D. 1907, Depression Position Finder was used from an elevation of 745 feet. The weather conditions were favorable, with only a moderate swell. The range varied from 10,000 to 12,000 yards. The attempt gave miserable results. A few shots that appeared short to the naked eye at the same station were changed by measurement into overs, and the effect of the lateral deviation of others was a complete mystery, baffling all calculation.

However, under a different set of conditions, the same method was entirely successful. This time the spotting station had an elevation of only 200 feet, but it was directly in rear of the battery, which was of intermediate caliber.
The ranges were in the neighborhood of 6000 yards.

Flank Spotting

The spotting station is located as nearly as possible on a line passing through the target at right angles to the line of direction. The field of fire must be flanked by an island or a bend in the shoreline, or must consist of a channel with contiguous shoal water where an inconspicuous raft or boat may be anchored and connected by telephone with the battery. In case the system is not provided with local range finding equipment, the battery must be provided with a device for estimating the distance from the spotter to the target. The spotter is equipped with a range-rake. He reads in mils, and multiplies these by a thousandth of his distance to the target, using a slide rule or a table which he has computed for this purpose.

The obvious improvement of this method is to combine two devices in one by eliminating the use of slide rule or table. This may be done by using a movable rake arm and setting it at that graduation on the handle which corresponds to the local range.

SPOTTING BOARD

First Method

This method is adapted for use with a baseline approximately equal to the greatest probable ranges, with a crescent shaped field of fire having spotting stations and battery at the horns of the crescent. By locating a spotting station on each flank, a more extended field of fire may be covered. Figure 2 shows by the shaded aria, the field effectively covered by this method, using two spotting stations, B′ and B″. The limiting exterior arcs are determined by the difference chart principle, using a limiting angle of 70 degrees, the interior arcs by a limiting angle of 110 degrees, these angles being considered the greatest allowable departures from 90 degrees.

Figure 3 shows the spotting board. Radial lines are drawn from B′ at angular intervals of a degree, and numbered with the nearest whole degree of azimuth. Similarly, radii are drawn from B, except that their interval is 5 degrees. The spotter is located at the battery, and sticks a pin in the board at the intersection of radii nearest the location of the target. The overs and shorts are deflections when measured from B′, and the observer reads them in hundredths of a degree and telephones them to the spotter, who sticks a second pin on the same line of direction with the first, at the proper estimated distance therefrom, considering the entire intercept between successive degree lines as one whole degree of deflection. He measures the number of yards between the pins by a ruler graduated to the scale of the board.

The method relies on the supposition that the component of the spotting lateral coordinate of the over or short which is due to its deflection, is inappreciable. This being the case, the method can be used only when the lines from the spotting station intersect the lines of direction at nearly 90 degrees, which immediately classes this method with flank spotting, the difference being that in flank spotting the estimate is mechanical, by reading the amounts directly from scales on the rake-arm, whereas, here it is geometrical, and the angular over or short is measured by an instrument.

The method having been used with great success by a rapid fire battery having a 3400 yard base line, the same method was tried by a contiguous major caliber battery, using the same spotting station, but was a total failure owing to the much greater ranges used.

The following departure from this method is suggested. Construct the spotting board as previously indicated. Rule a sheet of paper with horizontal lines and vertical columns. At the heads of columns place the azimuths from B. At the ends of lines place those from B′. From the board measure at each radial intersection the distances apart at the radii from B′ in yards. Divide this number by 100, and place the integral digit in the proper line and column. The spotting board is then discarded, and the battery commander, as soon as he receives the hundredths of a degree left or right from B′, selects the proper multiplier from the chart and mentally performs the multiplication. His product is the over or short.

Another excellent variation of this method is given by Major G. Ralph Meyer's article.

Second Method

This method makes allowance for the component of the spotting lateral coordinate, but by complicating the foregoing method, takes away the speedy operation which is its chief claim to efficiency. This method, properly simplified, is the same as the previous method, except that a table is computed giving the corrections in yards to be added or substracted at different points of the board for each hundredth of a degree of deflection measured at B.

One objection to the method is that the board must be on a very much larger scale than the plotting board. With a large field of fire including long ranges, this gives a board whose size is prohibitive.

The method described above is not as speedy as the first SPOTTING BOARD method, but in general is a very good method. As described in the 1913 article, (See Part II, A) it was somewhat slower.

The mechanical device described by L. A. McLaughlin applies this method, but being rather delicate and complicated, its mechanism is not very well adapted to the moderately rough handling which fire control apparatus unavoidably receives.

PLOTTING BOARD SPOTTING

This method is adapted for any horizonal base and very nearly meets the requirements of a universal method, but requires too great a degree of skill from the personnel to be considered truly effective. In this method, primary and secondary cease following the target long enough to observe on the splash. The plotter must hurry his work sufficiently to plot the splash between regular plottings, and must interpolate the latter when an observation on the target is lost. The only way of avoiding such irregularity with its likelihood of confusion, is to time the tripping and firing so that the time of flight gives a splash several seconds before an observing bell. There is then ample time for average observers and plotters to perform their functions without haste or confusion. The range officer measures or estimates the over or short from the track.

The personnel of a six inch battery were trained in the use of this method previously to service practice, and the plotting of shots was carried out during the practice. The range officer estimated the overs and shorts. The results were compared after the practice with those obtained from the camera, and were actually nearer to the latter than those computed from the range-rakes or the tug. The battery commander had never tried spotting before, and did not have sufficient confidence to use the data during the practice.

The use of this method is suggested when two instruments are available for use at each base end,—one for plotting and one for spotting, with a separate plotting board on which splashes only are plotted, measuring by the gun arm of this board the range to the splash, and substracting therefrom the actual range to the target. The latter range may be obtained from a time-range board on which actual ranges are kept instead of the customary corrected ranges.

"Observer's" suggestions also apply to this method.

BALLOON SPOTTING

By the use of the captive balloon, a greater elevation than that afforded by high ground may be obtained for use in vertical spotting. Then again there are other advantages afforded by balloon observation. Balloons are chiefly used for the purpose of overcoming the principal difficulty encountered in terrestrial observation, that of lack of visibility due to intervening ground forms and screens. For this purpose captive balloons may be employed as observing stations whenever good terrestrial stations are not obtainable. This is equally true for all known methods of spotting which rely upon stationary observation.

AEROPLANE SPOTTING

Aeroplane Spotting is an extensive subject by itself, and only two of the many methods which have been used will be indicated here. These seem to be adapted for Coast Artillery experiment.

First Method

A trained observer has a very good idea of the approximate size of a large naval target. He is thus able to judge by comparison the range deviation of shots stricking almost directly beneath him. He is likewise very well able to estimate range deviations when he happens to be on the flank. It is thus seen that his efforts are productive of the best results when his flights are confined to the plane containing the target and perpendicular to the line of direction.

Second Method

In the case of submarine or small targets of unknown dimension, a range rake is adjusted for the observer's elevation, and flight during moments of observation is confined to small circles about the target at a considerable elevation.

BILATERAL SPOTTING

Index Method

In Fig. 4, RS is perpendicular to the line of fire BT at T. B′ and B″ are observers' positions. Draw the circle B′TB″. If we consider points outside the circle as over, and inside as short, observations for points between the circumference and the line RS only will be in error. This method can be used for sensings, but not for measurements of range deviations. Observer at B′ reports deflections to the right as positive, to the left as negative. The other observer reports right as negative and left as positive. The deflections are added algebraically. If the resultant index is positive, the shot is over, if negative, it is short.

Cotangent Method

The formula r equals (d plus d′) cot t′, deduced below in Part III, is modified to read r equals (d′ plus d″) cot t, when we shift the BC observer to B′. The same index rules are employed as in the previous method, but an actual measurement of deviation is obtained. The angle t given by the formula is the angle B′TB″.

The method is comparatively accurate for values of t from 5° to 30°.

The Burlingame-Collet Spotting Board utilizes this principle. There are two improvements of the latter Spotting Board which very greatly extent its usefulness. These are:

(a) The introduction of a variable factor in computing the K cot t′ table (see description in the May Journal), for the purpose of offsetting the error introduced by the assumption of certain approximations in the formula.

(b) The use of a book of computed K cot t′ tables having separate pages for fields of fire extending in different directions, and for fields of fire of different magnitudes. With this assistance, battery charts can be merely copied instead of laboriously computed.

LATERAL OBERVATION

This method may be used by a rapid fire battery or by a mortar battery not having direct observation from the battery. It is too slow for a Major Caliber Battery and uses too much ammunition. It consists of a bracketing adjustment on the Observer-Target line, by a single observer; and depends on sensings for range deviations. It calls for simultaneous range and deflection changes, and is used only for values of t′ between 30° and 60°. Several mechanical devices have been invented for its use, one of them being the well-known T O B chart. This chart has the target at the center, and is ruled into squares of convenient dimension. A pivoted arm is set at an angle to the lines forming the squares. This angle is equal to the observer's angular displacement. On the pivoted arm is a sliding transparent plat graduated in ranges along its side edges and in mils along its top and bottom edges. The necessary range and deflection changes are estimated by comparsion with the squares.

III. MATHEMATICS OF SPOTTING

A. Dispersion

The rectangle of dispersion shows the increasing probability of hitting as the center of impact approaches the target.

The smaller the rectangle, the less the probability of hitting when the center of impact cannot be placed at the center of the target, (See Part I.). But, during a particular firing, the magnitude of the rectangle of dispersion remains practically constant, hence the only way to improve the fire is by bringing the center of impact nearer to the center of the target.

If we cannot be positive that our firing data was correct before the first shot was fired, we should have expected our second shot to be at the target. But since we know that there is probably more or less error in the data, and since we do not know what influences may change the position of the center of impact, we expect all shots after the first to strike at the last determined position of the latter point.

Now if, as a result of observation, we correct the range after each shot sufficiently to expect the next shot at the target, we have for each shot (except the first), placed at the target the center of impact of all preceding shots. This will result in a greater number of hits for the average series than will uncorrected fire, in which the hits are more apt to be accidental and due as much to dispersion as to accurate range determination.

B. Trend of Center of Impact

Figures 6 and 8 are each a series of 3 shots fired without observation. Figures 7 and 9 are the same series when fired with corrections from observation of fire.

The corrections made in these series are each sufficient to place the next expected splash on the target. The entire deviation is corrected after the first shot, one half of the deviation of the second, and one third of the deviation of the third shot. It will be seen in Figs. 7 and 9, that each splash is as far from the expected splash as it is in Figs. 6 and 8. The location of the third splash in Fig. 9, is an accidental one, due to dispersion, and is exceptional. If the reader will make for himself a number of diagrams of uncorrected situations, and will work them out for corrected results, he will find that for any size of target he has more hits by corrected fire than he has on his uncorrected set of diagrams.

If we take any considerable series of shots, say 20 or more, and subdivide the series into separate series, grouping by successive threes, or other small groups, with a separate center of impact for each group, we shall see that the average group center is the same as the center for the whole series, but we shall also see in a majority of actually fired series of many shots each, that there may be plotted a curve connecting the subcenters. This curve indicates the migratory tendency of the group center of impact.

The migratory tendency has always been confused with dispersion, but is independent of dispersion proper and is due to unmeasurable fluctuations in atmospheric conditions, in powder temperature, in the temperature of different parts of the gun and carriage, and to the uncertainty of the movements of the target.

There would be no necessity for taking cognizance of this tendency if the group center, after commencing to wander from the target, was just as likely during the remainder of the series to return toward the target as it was likly to continue away from it. But this is not the case, and the tendency is very apt to take a decided trend in one direction.

When this direction is away from the target, the location of the group center may become very much further from the target than the last computed location of the center of impact of the entire series. In this case a correction for the location of the last group center would be more desirable than a correction for the location of the center of impact of the entire series. The more divergent the tendency, the more expedient it becomes to disregard previous location of the center of impact.

Long intervals between shots are logical group divisions.

C. Instrumental Observation

The mathematical principles here touched upon are based on formulas derived from measurements of horizontal and vertical angles at two stations. They apply to nearly all methods of Spotting.

Except in bilateral observation, one of the stations is in the immediate vicinity of the battery. The angles measured are limited to four, one vertical and three horizontal. The vertical angle itself is not used; instead, a more convenient function of the angle, its horizontal intercept on the water surface is employed. This intercept is the difference of the ranges to the target and to the splash as determined by a Depression Position Finder.

The horizontal angles are:

1. The observer's Lateral Displacement.
2. The deflection of the splash read in the spotting station instrument.
3. The deflection of the splash measured from the battery.

Three formulas are deduced as functions of the Observer's Lateral Displacement. The algebraic signs in these formulas change as t′ passes from acute to obtuse, and as B′ shifts from right to left of B. These sign changes follow trigonometrical rules, but for the sake of simplicity in the deduction, all trigonometrical functions will throughout at first be considered as positive. The coefficients, d, d′, and r′ will be positive when right or over, and negative when left or short. A resulting negative value of r indicates a short. The formulas will be deduced independently for right and for left handed base lines, and for acute and obtuse values of t′. The figures are intended only as models, and the deductions are as abbreviated as is consistent with clearness.

Vertical Formula For Single Station

Fig. 11 shows a left handed spotting station with an acute angle at the target.

TR′ is the projection on BT of r′. TR′ is therefore r′ cos t′, and is positive or negative to correspond to r′. DR′ is the projection on BT of d′. DR′ is therefore d′ sin t′, and is positive or negative to correspond to d′. The figure gives positive values of r′ and d′. r is found by substracting DR′ from TR′.

The formula therefore reads r equals r′ cos t′ less d′ sin t′. Any value of d′ which makes its projection greater than the projection of r′, gives a negative value of r for positive values of r′ and d′. When d′ is negative, d′ sin t′ is negative, and gives increasing values of r for increasing length of d′.

Similarly for a right handed station, r equals r′ cos t′ plus d′ sin t′. The formulae for obtuse angle values of t′, for left and for right handed stations are respectively

r equals minus r′ cos t′ minus d′ sin t′
r equals minus r′ cos t′ plus d′ sin t′

Otherwise, in Figure 11, using BT as an origin, divide the space about the target into quadrants in a counter-clockwise direction. Then B′ falls in the first, second, third, and fourth quadrants successively. Following the trigonometrical rule, the sine is positive in the first and second quadrants, and negative in the third and fourth. The cosine is positive in the first and fourth and negative in the second and third. This combines what were at first deduced as separate formulas, into the single formula, *r equals r′ cos t′ plus d′ sin t′.* The separate formulas will be found handier for the computation of tables by battery officers.

Vertical Formula For Two Stations

Considering trigonometrical functions positive, we have in Figure 12, TN equals r′ sec t′, and ND equals d tan t′. This gives the following formula, when t′ is acute and B′ is right handed, *r equals r′ sec t′ plus d tan t′.*

Likewise, for t′ acute, B′ left handed, *r equals r′ sec t′ minus d tan t′.* And with t′ obtuse and B′ right handed, *r equals minus r′ sec t′ minus d tan t′.* When t′ is obtuse and B′ left handed, *r equals minus r′ sec t′ plus d tan t′.*

Otherwise, applying the quadrant rule, B′ is in the first, fourth, second, and third quadrants successively, and since the secant is positive in the first and fourth quadrants, and negative in the others, with the tangent positive in the first and third, and negative in the second and fourth; the formulas merge into a single formula as follows, *r equals r′ sec t′ plus d tan t′*

Horizontal Formula

In Figure 13, considering functions as positive only, we have DM equals d cot t′, and TM equals d′ cosec t′. With t′ acute B′ right, *r equals d′ cosec t′ minus d cot t′.* Similar figures will give the following separate formulas. With t′ acute, B′ left, *r equals minus d′ cosec t′ plus d cot t′.* With t′ obtuse, B′ right, *r equals d′ cosec t′ plus d cot t′.* With t′ obtuse, B′ left, *r equals minus d′ cosec t′ minus d cot t′.*

Otherwise: Dividing the space about T into quadrants, but proceeding this time in a clockwise direction, and starting 180 degrees different than in the vertical formulas; we have B′ successively in the second, third, first, and fourth quadrants.

The cosecant is positive in the first and second quadrants and negative in the others. The cotangent is positive in the first and third quadrants, and negative in the second and fourth.

The combined formulas then becomes as follows, *r equals d′ cosec t′ plus d cot t′*

Part IV

Resumé and Critique

It may be seen from a further study and a few practical applications of the formulas of Part III, that the formulas furnished directly or indirectly the mathematical principles underlying the various methods. Before formulas can be applied practically a simplification is usually necessary. This is accomplished by the substitution of one or more approximations which give good results for the particular set of conditions favorable to the use of the method adopted.

For instance, consider the formula *r equals d′ cosec t′ plus d cot t′*, and you will see how it is modified in the following methods.

Flank Spotting

Since no correction is made for deflection, it is apparent that t is considered as 90 degrees. Cot 90 degrees equals zero. Hence the small d cot t′ term disappears. Cosec t′ equals unity. Hence the d′ cosec term becomes simply d′, and the formula becomes, r equals d′.

Spotting Board

In the First Method d is assumed to be zero, hence d cot t′ equals zero. If we rule a spotting line from the second pin, and a perpendicular to this line from the first pin, then the portion of the perpendicular intercepted by the Spotting Line and the first pin, represents d′. The distance between pins is easily seen to be d′ cosec t′. Hence we obtain the formula r equals d′ cosec t′. The Second Method uses the whole formula.

Plotting Board

Plot the target at the moment of impact and diagram as in the deduction of the formula. All elements are present. Hence the formula remains, *r equals d cot t′ plus d′ cosec t′*. Any inaccuracy from this method is the result of individual variation in applying it to abtain the factors appearing in the formula.

Vertical Spotting

The vertical formulas apply to vertical spotting as described in Part II. We repeat them here. They are *r equals r′ cos t′ plus d′ sin t′*, and *r equals r′ sec t′ plus d tan t′.*

The tried method neglects both d and d′. Hence the second terms disappear in both equations. The value of t′ is neglected, hence, cos t′ and sec t′ both equal sec 0 degrees, which is unity. The formulas thus become, r equals r′.

OTHER APPROXIMATIONS ALLOWABLE

It would be better in Horizontal Spotting not to neglect d when t′ is about 90 degrees, but rather to consider cosec t′ equal to unity. The formula thus becomes, r equals d′ plus d cot t′. When t′ has a very small value, consider cosec *t′* equals to cot t′. Then we have, *r equals (d plus d′) cot t′*, This formula furnishes the basis for the Burlingame-Collet Spotting Board.

In vertical spotting, when t′ is very small, d and d′ may be neglected, making r equal to r′, but when t′ is nearly 90 degrees, assume sec t′ equal to tan t′. Thus r becomes equl to (r′ plus d) tan t′, for double station, and r equals d′ for single.

The essential limitation to the scope of many of the tried methods lies in the fact that an effort is made to compute the value of r from a single measured quantity. We will, therefore, add a series of outlined methods evolved from a determination of "r" based upon the measurement of certain additional quantities considered in the formulas of Part III, more or less erroneously neglected in some of the methods of Part II. Corresponding with each formula are two solutions, one graphic and one computative.

Graphic Spotting

The graphic solution may be accurately obtained by a neat and rapid drawer, and if the spotter has also a good eye for proportions and measurements, the diagram may be roughly sketched and distances estimated by eye with sufficient accuracy. A method will be outlined for each formula.

Vertical Methods With One Station

Construct a chart or table giving value in yards of convenient deflections at each probable range B′T. Take the value of d′, in figure II, from the table.

Construct a chart giving values of t′ at each range and azimuth from B′. Draw B′T and BT. Prolong these lines.

Lay off r′ and d′. Draw SD perpendicular to BT. Measure r to scale.

Vertical Method With Two Stations

(See Fig. 14)

Find d in yards from a chart as for d′. Construct t′ as before. Lay off TR equal to r′, and draw RN perpendicular to TR. Prolong RN. Draw XY parallel to TN at a distance from it equal to d. The intersection of RN and XY gives S. Find r as before.

Horizontal Method (See Fig. 15)

Construct charts or tables giving values in yards of convenient deflections for B and B′ at probable range and azimuth from B.

Draw SA and SX parallel respectively to B′T and BT, at distances therefrom respectively equal to d′ and d. The intersection of the parallels gives S. Draw TX perpendicular to BT. Measure SX by scale to obtain value of r.

Computative Solutions

It will be seen as "t′" approaches 90 degrees that cos t′ approaches zero, that sin t′ approaches unity, and that tan t′ and sec t′ becomes infinite. The vertical formula *r equals r′ sec t′ plus d tan t′* thus becomes useless for such values of t′, but even so, it is useful for values very much in excess of the 20 degrees or so allowed by the Vertical Method of Part II. The vertical formula *r equals r′ cos t′ plus d′ sin t′* is effective for all values of t′ since both terms cannot approach zero at the same time, nor either term exceed its r′ or d′ factor.

In the horizontal formula, *r equals d′ cosec t′ plus d cot t′*, the second term becomes infinite as t′ approaches zero. Hence this formula may not be used for values of t′ less than about 5 degrees. However, by sufficiently extending the base-line, a value in excess of 5 degrees may always be secured.

VERTICAL METHODS FROM THE ONE STATION FORMULA

In addition to the observer and reader, the spotting section may consist of three men. For convenience let us call them the "sine" man, the "cosine" man, and the "adder." The "cosine" man has a table on which a T-square is set for ranges, there being on the T-square an index which is set for azimuths.

The index points to the value of cos t′. The "cosine" man keeps this table set continously. He has another table on which a T-square is set continuously for cos t′. When the reader calls the value of r′, the "cosine" man sets the index on the latter T-square at the value of r′ received and calls from the table the value of r′ cos t′. The "sine" man has a table giving k′ sin t′ from the ranges and azimuths. K′ is one of the factors of d′ the other being the deflection. K′ equals $\frac{\pi R'}{100x180}$. Since K′ depends only on the range, it may readily be incorporated in the sine table. He keeps his second table set for k′ sin t′ and sets his index for the deflection when it is called by the reader, and calls out the value of d′ sin t′. The adder combines r′ cos t′ and d′ sin t′ by means of a slide rule or a table. The battery commander should know the result of the spotting about ten seconds after the splash. The tables indicated require only ordinary ingenuity for their construction, care being exercised in the selection of the ranges, azimuths, deflections, and values of r′ used in the margins. A more detailed description is considered quite unnecessary for the construction of the tables by Coast Artillery officers.

VERTICAL METHOD FOR THE TWO STATION FORMULA

This method is similar to the one just described, except that the "secant" man and the "tangent" man are at the battery with head sets leading to the stations, and using ranges and azimuths from the battery, instead of the spotting station.

LATERAL METHOD: HORIZONTAL FORMULA

A method similar to the above was tried out by the author in horizontal spotting, and gave satisfactory results, but was discarded in favor of the Burlingame-Collet Spotting Board, owing to the greater simplicity and consequent freedom from errors of the latter board. The accuracy and speed were pratically the same for both methods. The two-board method, however, will be found superior to the Burlingame-Collet method if the angle t′ lies between 30 and 60 degrees. The method has great possibilities, but as yet has not been thoroughly tried with a view to improvement.

We have, then, a score of methods from which to select one or more for a certain battery. We must not select a method which we like for its simplicity and try to make it work under conditions not suited to the method. We must, rather, make a list of methods suited to the conditions obtaining at the battery, review the possibilities of the methods listed, and then select two or three for trial, retaining those methods which practice determines to be most satisfactory; if possible, a single satisfactory method.

Equations of Differential Variations in Exterior Ballistics

By W. E. Milne

In the preparation of range tables it is necessary to determine not merely the ranges corresponding to given elevations for the gun in question but also the variations in range caused by small changes in muzzle velocity, ballistic coefficient, air density, etc. While it is possible to determine these variations by computing a new set of trajectories for each new condition, it is easier in practice to use a set of equations, called "equations of differential variations," the solutions of which give the variations in the trajectory directly. The original derivation of these equations and the recognition of their importance is due to Major F. R. Moulton of the Ordnance Department. The equations derived by Major Moulton yield not only the change in range due to any of the above mentioned causes, but also give the variation in time of flight, angle of fall, and in the position of the projectile at corresponding times throughout the entire trajectory. In this respect they have certain advantages over the briefer method using adjoint systems,* which yields the change in range only. They may also be used to determine the effect on the trajectory of any small change in the law of air resistance, a matter of importance if experiment should show that the law now used ought to be modified.

The derivation of the equations given here is different from the one used by Major Moulton, and the equations themselves are slightly simpler. No knowledge of mathematics beyond differential and integral calculus is needed to understand the methods and results.

As usual in ballistics, the origin O is taken at the gun, the axis of Y vertical, and the axis of X horizontal. The coordinates of the projectile at time t are x and y, the velocity is v, the inclination of the path is denoted by θ, and the mass of the projectile by m. The notation $\frac{dx}{dt} = x'$, and $\frac{d^2x}{dt^2} = x''$, etc., is used throughout. It is assumed that in still air the force R due to air resistance acts directly apposite to the motion of the projectile, and hence is tangent to the path. Therefore the equations of motion under normal conditions are

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*An account of this method will appear in the September issue of the Journal.

$$mx'' = -R\cos\theta,$$
$$my'' = -g - R\sin\theta.$$

Since $\cos\theta = x'/v$ and $\sin\theta = y'/v$, let us set $R/mv = F$, and put the equations in the form

$$(1) \qquad \begin{aligned} x'' &= -Fx', \\ y'' &= -g - Fy'. \end{aligned}$$

The function F can be written

$$(2) \qquad F = \frac{H\,G(v)}{C},$$

in which C is the ballistic coefficient, H is the ratio of air density at altitude y to normal surface density, and G(v) is a function of the velocity only .

Suppose that the trajectory OPQ (Fig. 1) has been computed under normal conditions. Now suppose that because of a small change in the air resistance, or in the initial conditions, the projectile deviates from the normal path and follows the path $O\bar{P}\bar{Q}$.

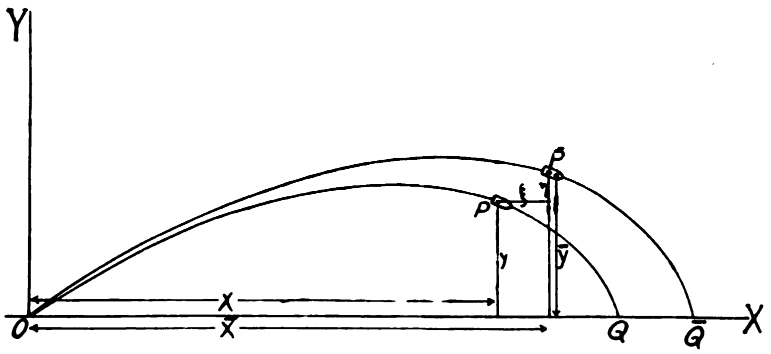

Fig. 1

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Let $\bar{P}(\bar{x},\bar{y})$ be the position of the projectile on the modified path at the same moment of time that it would be at P(x,y) on the normal path. With the assumption that the force of air resistance $\bar{R}$ on the new trajectory is also tangent to the path, the equations for the modified motion are

$$(3)\qquad \begin{aligned} \bar{x}'' &= -\bar{F}\,\bar{x}', \\ \bar{y}'' &= -g - \bar{F}\,\bar{y}', \end{aligned}$$

in which

$$\bar{F} = \frac{\bar{R}}{m\bar{v}}.$$

Let

$$(4)\qquad \begin{aligned} \bar{F} - F &= \delta F, \\ \bar{x} - x &= \xi, \\ \bar{y} - y &= \eta, \end{aligned}$$

and substitute for $\bar{x}$, $\bar{y}$, and $\bar{F}$ in (3) their values given by (4). The result is

$$(5)\qquad \begin{aligned} x'' + \xi'' &= -Fx' - F\xi' - \delta F.x' - \delta F.\xi', \\ y'' + \eta'' &= -g - Fy' - F\eta' - \delta F.y' - \delta F.\eta'. \end{aligned}$$

Now the products $\delta F.\xi'$ and $\delta F.\eta'$ are small quantities of the second order compared with ξ and η, and for small variations they may be neglected without errors of practical importance. Then when we substitute for x'' and y'' their values from (1), equations (5) become

$$\begin{aligned} \xi'' + F\xi' &= -\delta F.x', \\ \eta'' + F\eta' &= -\delta F.y'. \end{aligned}$$

Here we replace F by $-x''/x'$, obtained from the first equation of (1), and divide through by x', upon which we have

$$\frac{x'\xi'' - \xi'x''}{x'^2} = -\delta F,$$

$$\frac{x'\eta'' - \eta'x''}{x'^2} = -\frac{y'}{x'}\delta F,$$

where the left hand sides are exact derivatives. Let the initial values of x', ξ', and η' be denoted by x'_0, ξ'_0, and η_0' respectively. Then we integrate from $t = o$ to $t = t$, multiply by x', and get the equations

$$(6)\qquad \begin{aligned} \xi' &= x'\left\{\frac{\xi_0'}{x_0'} - \int_0^t \delta F\,dt\right\}, \\ \eta' &= x'\left\{\frac{\eta_0'}{x_0'} - \int_0^t \frac{y'}{x'}\,\delta F\,dt\right\}. \end{aligned}$$

To use these equations, we must find an explicit expression for δF. It is seen from (2) that F may vary because of changes in C, H, or G. Now H may vary because its argument y is different on the new path, or because of a change in air density, or both; similarly G may vary because v is changed, or because the law of resistance is changed, or both. Let δC denote the change in C, δH the change in H due to a change in air density only, and δG the change in G due to a change in the law of retardation only. The change in H due to a change in y only is $H(\bar{y})-H(y)$, and by the mean value theorem this equals $\frac{dH}{dy}(\bar{y}-y)$, or $\frac{dH}{dy}\cdot\eta$, to terms of the first order. Similarly the change in G due to a change in v only is $\frac{dG}{dv}(\bar{v}-v)$. Now $v^2=x'^2+y'^2$, so to terms of the first order $\bar{v}-v=(x'\xi'+y'\eta')/v$.

The total variation in F due to all causes combined is the sum of the variations due to separate causes, so

$$(7)\quad \delta F=F\left(-\frac{\delta C}{C}+\frac{\delta H}{H}+\frac{\delta G}{G}+\frac{\frac{dG}{dv}}{vG}\left\{x'\xi'+y'\eta'\right\}+\frac{\frac{dH}{dy}}{H}\cdot\eta\right)$$

to terms of the first order.

The equations (6) and (7), together with the two equations

$$(8)\quad \begin{aligned} \xi &= \int_0^t \xi'\,dt, \\ \eta &= \int_0^t \eta'\,dt, \end{aligned}$$

constitute the general equations of differential variations. Their solutions give us ξ and η, ξ' and η' as functions of t, and thus, as Fig. 1 clearly shows, we have the variation in the position of the projectile at corresponding times. It is then easy to compute the change in other elements, such as range, time of flight, angle of fall, etc.

For the solution of equations (6), (7), and (8) it is necessary to know:

(a) The quantities x, y, x', y', v, and F as functions of t on the normal trajectory. These are all obtained in the course of the computation of the trajectory, and are therefore at once available.

(b) The quantities $\xi_0', \eta_0', \delta C, \delta H$, and δG. These depend on the nature of the changes that cause the variation in the trajectory, and come under various special cases. We shall obtain the special forms of the equations for several important cases.

A. When the ballistic coefficient alone is varied $\xi_0'=o$, $\eta_0'=o$, $\delta H=o$, and $\delta G=o$, so from (6) and (7) we have

$$\xi' = -x'\int_o^t F\left[-\frac{\delta C}{C}+\frac{\frac{dG}{dv}}{vG}\left\{x'\xi'+y'\eta'\right\}+\frac{\frac{dH}{dy}}{H}\cdot\eta\right]dt,$$

(9)

$$\eta' = -x'\int_o^t y'\frac{F}{x'}\left[-\frac{\delta C}{C}+\frac{\frac{dG}{dv}}{vG}\left\{x'\xi'+y'\eta'\right\}+\frac{\frac{dH}{dy}}{H}\cdot\eta\right]dt.$$

B. For a change in air density only, or

C. a change in the law of air resistance only, we have equations similar to (9) with $-\frac{\delta C}{C}$ replaced by $\frac{\delta H}{H}$ or $\frac{\delta G}{G}$ respectively.

D. In case of a change $\delta\varphi$ in the angle of departure, or a change δV in muzzle velocity, or both together, we have $\delta C=0$, $\delta H=0$, $\delta G=0$, and to terms of the first order

$$\xi_0' = \delta V\cos\varphi - V\sin\varphi\ \delta\varphi,$$
$$\eta_0' = \delta V\sin\varphi + V\cos\varphi\ \delta\varphi,$$

where φ is the angle of departure and $\delta\varphi$ is measured in radians. These values substituted in (6) and (7) give the desired equations.

E. The effect of a horizontal wind of velocity u in the direction of fire is, for the motion of the projectile relative to the air, equivalent to a decrease of u in the horizontal component of velocity. That is, if $\bar{\xi}'$ and $\bar{\eta}'$ are the differences between the components of velocity in still air and the corresponding components relative to the moving air, then $\delta C=o$ $\delta H=o$, $\delta G=o$, $\bar{\xi}'=-u$, and $\bar{\eta}_0'=o$, so we have

$$\bar{\xi}'=x'\left[-\frac{u}{x_0}-\int_o^t F\left\{\frac{\frac{dG}{dv}}{vG}\left(x'\bar{\xi}'+y'\bar{\eta}'\right)+\frac{\frac{dH}{dy}}{H}\cdot(\eta)\right\}dt\right],$$

$$\bar{\eta}'=x'\left[-\int_o^t \frac{y'F}{x'}\left\{\frac{\frac{dG}{dv}}{vG}\left(x'\bar{\xi}'+y'\bar{\eta}'+\right)\frac{\frac{dH}{dy}}{H}\cdot(\bar{\eta})\right\}dt\right].$$

If ξ and η denote the changes in the coordinates of the projectile relative to the ground,

$$\bar{\xi}' = \xi' - u,$$
$$\bar{\eta}' = \eta',$$

and these values substituted above give the final equations

$$\xi' = u\left(1 - \frac{x'}{x_0'}\right) - x'\int_0^t F\left\{\frac{\frac{dG}{dv}}{vG}\,(x'[\xi' - u] + y'\eta') + \frac{\frac{dH}{dy}}{H}\cdot\eta\right\} dt,$$

$$\eta' = -x'\int_0^t \frac{y'F}{x'}\left\{\frac{\frac{dG}{dv}}{vG}\left(x'[\xi' - u] + y'\eta'\right) + \frac{\frac{dH}{dy}}{H}\,\eta\right\} dt.$$

The reader has noted that at many points in the demonstrations terms involving ξ, η, etc. to an order higher than the first have been dropped, and he perhaps entertains grave doubts of the value of results so obtained. Numerous computations have shown that for the variations ordinarily encountered in practice, these equations give all the accuracy required for the construction of range tables. Major Moulton has also made a careful theoretical investigation of the errors committed, and has found that they are immaterial for ordinary variations.

In solving these equations of differential variations recourse is had to the numerical methods of solution explained by Major Moulton in the July issue of the U. S. Artillery Journal; for of course a formal solution in terms of known functions is impossible. The form in which the equations are expressed is well adapted to numerical computations, as the unknowns, ξ, η, ξ', and η', are involved in the most simple manner possible. In fact it will be of interest to mathematicians to note that δF is linear in ξ', η' and η are so that equations (6) and (8) form a system of simulataneous linear integral equations.

Coast Defenses Constructed by the Germans on the Belgian Coast

Submitted by Major Augustus Norton, C. A. C., and
Major Donald Armstrong, C. A. C.

PART III

BATTERY TIRPITZ

A four 28-cm. gun battery of the South Ostende Group.

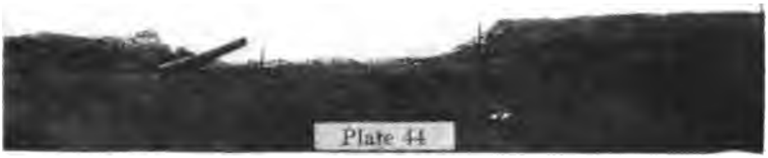
The first major caliber battery to be installed on the Belgian coast was battery Tirpitz, consisting of four 28-cm. guns on front pintle barbette carriages, capable of all round fire. Work of construction commencing in 1915, was far advanced toward the end of the year, but the battery did not actually fire until about the middle of 1916. The problems involved in construction were undoubtedly difficult to solve as the ground is marshy and a large number of piles must have been sunk to provide a suitable foundation for the gun and its mount which were very heavy. The battery is located about one kilometer from the shore line in an open field southwest of Ostende. Its front in a generally north and south direction covers about 200 meters, the distance between guns being 45 meters. The guns are in a straight line, each magazine located to the left of the gun it serves, and being on the same level. There was earth cover of about one meter thickness over the concrete roof of each magazine which thus formed a low traverse between each piece. In consequence the fire from each gun to the south was blanked for elevation up to about three or four degrees, but this was a matter of no importance as targets in this area required minimum elevations of about fifteen degrees.

A power plant was located on the right flank together with shelters for the personnel. The concrete overhead cover for magazines and shelters was always at least three meters thick. A data booth was located to the right front and here all data for laying in elevation and azimuth was apparently posted.

The position was elaborately prepared for local defense with barbed wire entanglements, concrete machine gun position and trenches. A parados was located in rear of each gun and a concrete wall about a meter thick was placed in front of each magazine door to provide protection against shell fragments.

Gun

The guns were manufactured in 1911 and are 40 calibers in length. The breech is the usual Kruppe wedge system.



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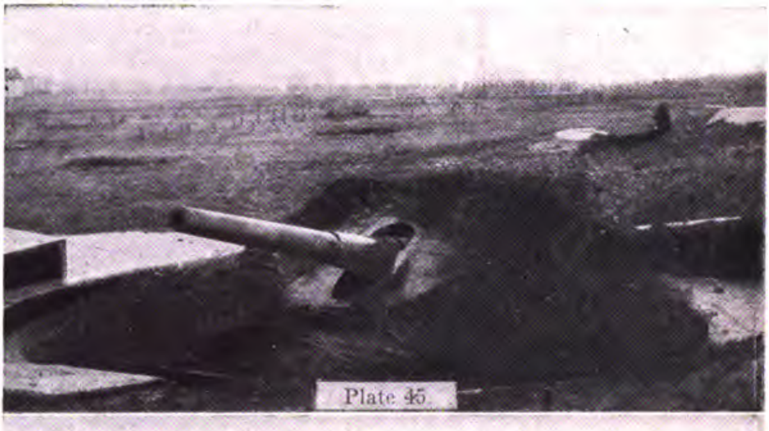
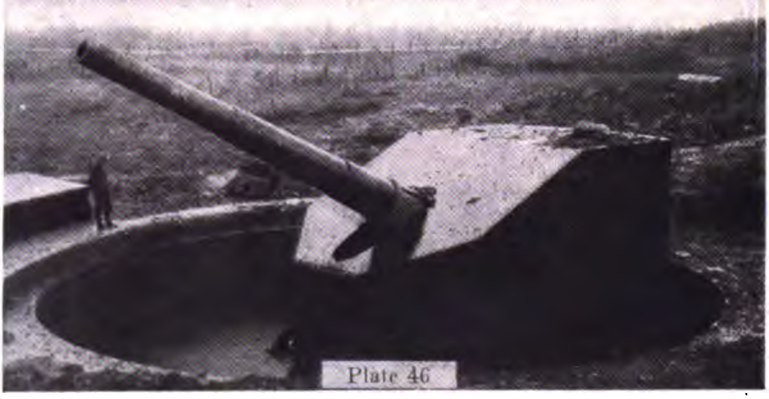
(Top) Battery Tirpitz, 28-cm. guns. A general view of the battery from the front. Note that the shields are not outlined against the sky-line.

(Middle) Battery Tirpitz, 28-cm. guns. A general view from the left flank taken from the top of the traverse. Note the comparatively low traverses between guns.

(Bottom) Battery Tirpitz, 28-cm. guns. A view of one of the emplacements from the front. The camouflage is still in place on the shield. Note how the outlines of the shield are obliterated and the camouflage blends with the background.





(Top) Battery Tirpitz, 28-cm. guns. A close view of the same gun showing how the camouflage is applied.

(Bottom) Battery Tirpitz, 28-cm. guns. A close view of one of the guns. Note the depth of the well and the front pintle mounting, also the extension of the shield below loading platform to protect traversing mechanism.

Cradle

The gun is mounted in a cradle resting on two trunnions with three cylinders above and the same number below, there being thus four hydraulic recoil cylinders and two recuperators.

Carriage

The carriage is composed of two side frames of girder construction, with the usual transoms.

(1) The front of the side frame is supported through the medium of a massive steel pin in a yoke bolted to a ball bear-

ing pivot supported on a steel pedestal. The base of the pedestal is about two meters below the base of the loading platform.

(2) The rear of the carriage rests and is traversed on four large traversing wheels with bearings in the rear transom.

Elevating mechanism

Laying for elevation is accomplished by means of two cir-

Plate 47

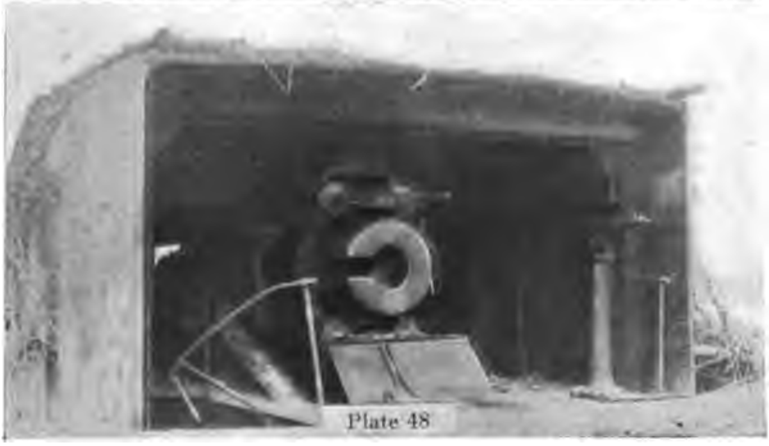


Plate 48

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(Top) Battery Tirpitz, 28-cm. guns. Concrete power plant on right flank. Note the decorative concrete work, the name of the battery and the date.

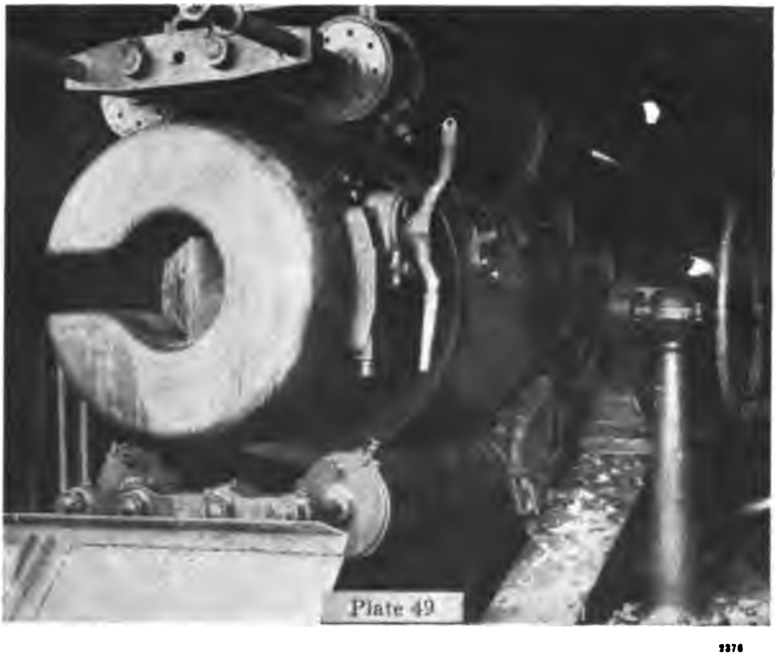
(Bottom) Battery Tirpitz, 28-cm. guns. A close view of one of the pieces. Note the carefully painted table of figures on right hand side of shield, so posted as to be easily seen from a data computing device mounted on the pedestal shown at the right.

cular racks bolted to the bottom of the cradle with which mesh two spur pinions operated through worm and bevel gearing, by two handwheels on the loading platform on the right side of the gun. It was impossible to determine the maximum elevation, but the guns of this battery have been known to fire up to a range of 25 km.

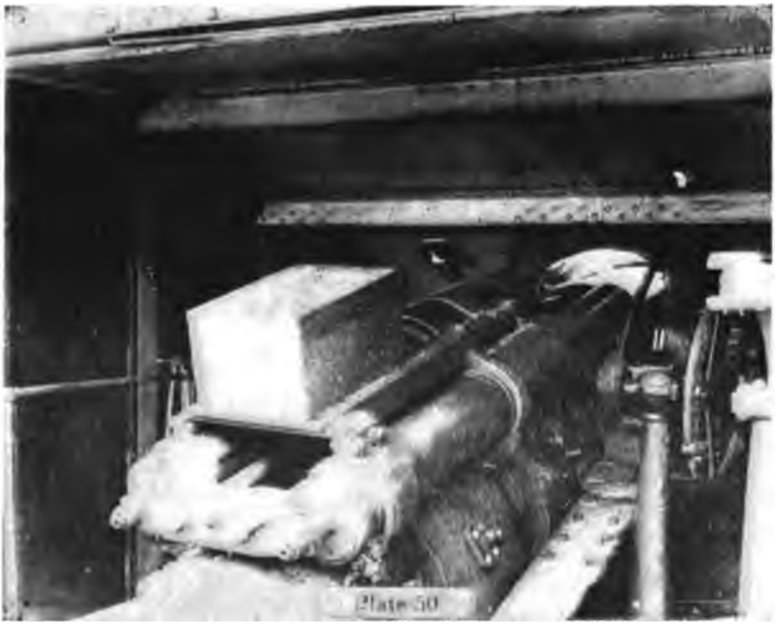
Traversing mechanism

The piece was laid in azimuth by a handwheel on a platform below and to the left of the loading platform. The handwheel operated a series of bevel and spur gearing, motion being finally transmitted to a spur gear bolted to the front face of the left traversing wheel.

Both operations of traversing and elevation were accomplished by hand alone.



Battery Tirpitz, 28-cm. guns. Right side view of breech showing operating handle. Elevating handwheel shown at the right.



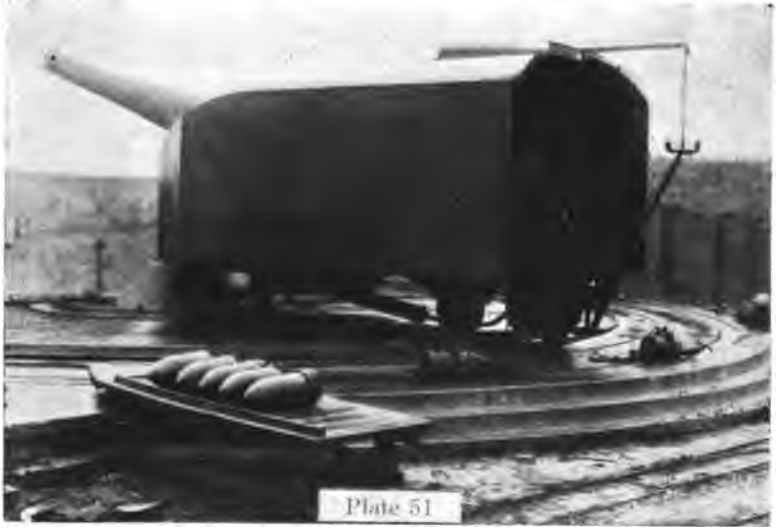
Battery Tirpitz, 28-cm. guns. Looking down on upper set of recoil and recuperator cylinders. Note the counterpoise. The range scale bracket is shown at the forward end of the right hand recuperator cylinder.

Battery Hindenburg

A four 28-cm. gun battery of the North Ostende group.

These guns and carriages were of an early model, the guns having been manufactured in 1887. The velocity used was 455 m/s with a 240-kg. projectile. The carriage permitted elevations from −5° to +17°. The guns were arranged in line with an interval of about 30 meters between guns. There was a traverse between each emplacement and magazines on each flank. All re-inforced concrete was used throughout. The details of the gun emplacement are clearly shown in the pictures following.

The recoil system was primitive; the top carriage recoiled on inclined planes formed by the tops of the sides of the chassis. The traversing and elevating mechanisms were also very simple. A chain anchored at both ends and a sprocket operated by a crank through a simple system of gears provided the means for laying in direction. The elevating system consisted of a



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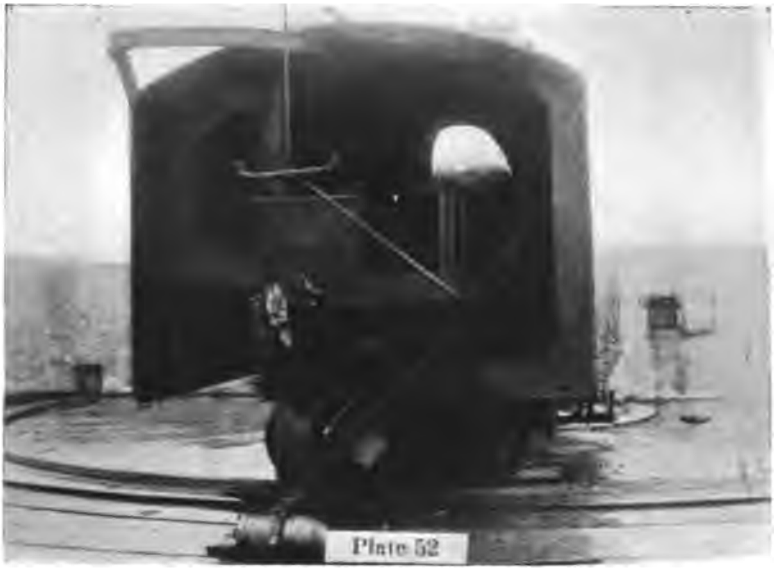
Battery Hindenburg, 28-cm. guns. General view of one piece and its emplacement. Note the peculiar mounting. This matériel was very old.



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Battery Hindenburg, 28-cm. guns. A rear view of one of the guns.

very simple system of gears operating a pinion which engaged the elevating rack.

The construction of the emplacement permitted a traverse of nearly 180°. The battery was within about 500 meters of the shore.

Battery Schliesen

A four 17-cm. gun battery of the North Ostende group.

This and battery Oldenburg were the only batteries of the intermediate armament that were located back of the shore line. This battery was located about three kilometers back of the shore and was the farthest removed of any of the coast batteries.

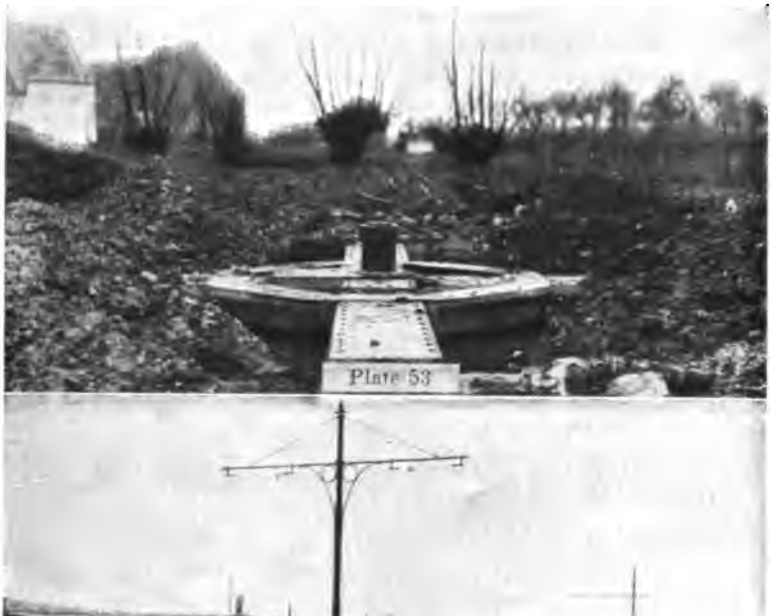


Plate 53

Plate 54

2230

(Top) Battery Schliesen, 17-cm. guns. Iron framework on which gun platform and carriage is mounted. This was all that remained of the battery.

(Bottom) Battery Groden, 28-cm. mortars. General view of the battery.

Nothing is known regarding the character of the mounting. Everything but the foundation framework had been removed.

The guns were disposed on the parallelogram pattern.

The whole battery was very much out in the open. An inspection of the magazines indicated that this battery had been completed at least two years ago, 1916.

BATTERY GRODEN

A four 28-cm. mortar battery of the Zeebrugge grouping.

Very little remained of this battery except the emplacement.

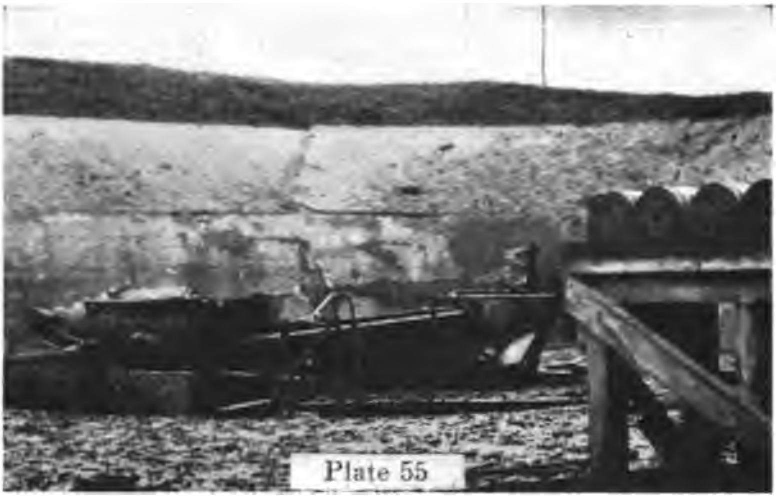
An examination of what remained of the carriages indicated that these mortars were not of recent design.

There were four shallow pits with about 45 meters interval between pieces. Each pit contained a single piece. A traverse between each pit containing a magazine and on the flanks were shelters for the personnel.

This was the only mortar battery found on the entire coast.

It was located close to the shore line and just in rear of the line of dunes.

An examination of the battery indicates that it had been in existence for at least two years.



Battery Groden, 28-cm. mortars. Interior view of one of the pits.

Battery Oldenburg

A four 17-cm. gun battery belonging to the South Ostende Group.

Whereas there are practically no mechanical features worthy of note in connection with this battery its novelty compels some recognition being given to it.

This battery was situated about one kilometer from the shore line. The guns were disposed in the four corners of a parallelogram. The plan of each emplacement was different except for the gun platform. This variation in plan conveyed the impression that the guns were disposed irregularly whereas in reality they were not. The concrete structure which formed the magazine and quarters for the personnel was camouflaged to resemble a fisherman's cottage, such as existed in the vicinity. A false roof of brush was clearly applied. The gun emplacement proper was hidden from aerial observation by

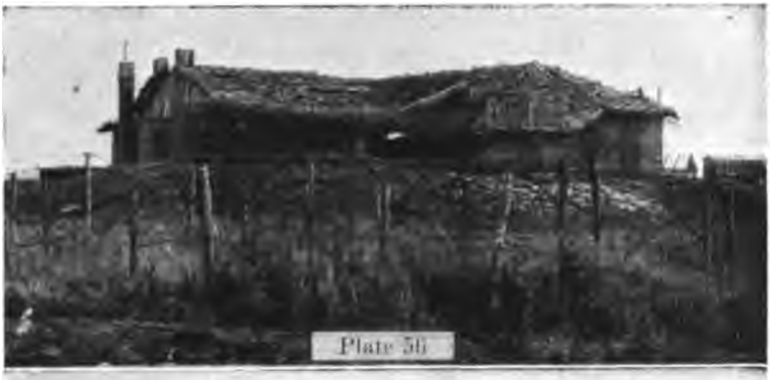


Plate 56

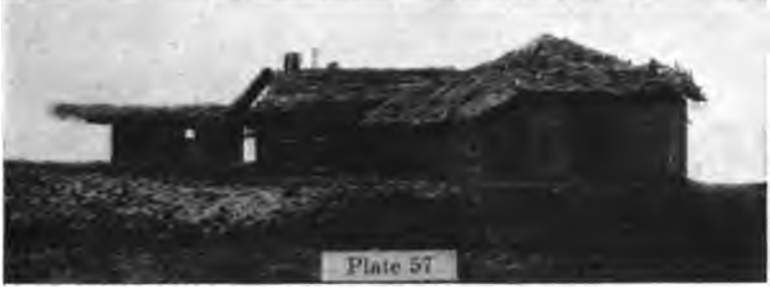


Plate 57

(Top) Battery Oldenburg, 17-cm. guns. A general view of one of the emplacements. The camouflage mat is still in place on top of gun shield, No. 1 gun.

(Bottom) Battery Oldenburg, 17-cm. guns. Another view of No. 1 gun.

means of a brush mat, the same matériel as used on the roof. This would give the impression from above that this formed an extension of the imitation house.

The guns and carriages were probably removed from some warship as the original shield attached to the carriage was of the type used in sponsons, the side and top plates were added when these guns were to be used on shore.

Plates 56 to 60 inclusive will give some idea of the deception and the originality used in camouflaging this battery.

There was no evidence that this battery had ever been fired on but it was detected while under construction and marked as a battery on the French Plan Directeur.

It may be of interest to state that this battery was hard to find when the writers were searching for it. Its general location was known. The data booth was the first thing seen and this was spotted because of its regularity of outline. The battery was thought to be near, which was the case, but the guns of No. 1 and 4 could not be seen until within less than a

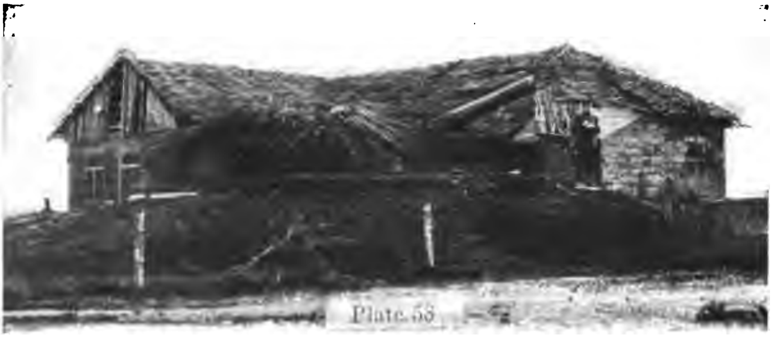


Plate 58

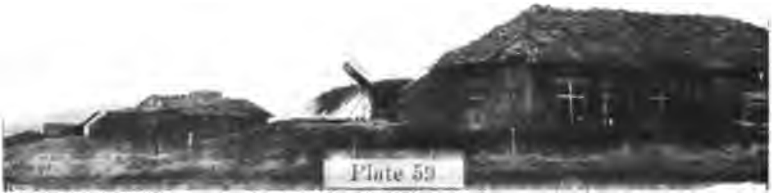
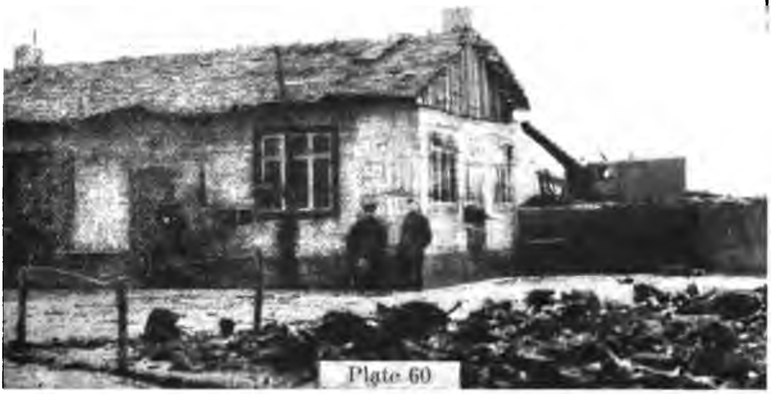


Plate 59

(Top) Battery Oldenburg, 17-cm. guns. General view of No. 4 emplacement.

(Bottom) Battery Oldenburg, 17-cm. guns. Another view of No. 4, with No. 3 in the background. Note the realistic effect of the painted windows and doors.

hundred meters. The camouflage mat was missing on No. 2 and 3 and they were more prominent.



Battery Oldenburg, 17-cm. guns. A view of No. 2 emplacement.

Palace Hotel Battery

A four 17-cm. gun battery which was un-named and has been so called by the writers for purpose of identification and reference. This battery is typical of the intermediate armament but does not embody any new ideas or features of note.

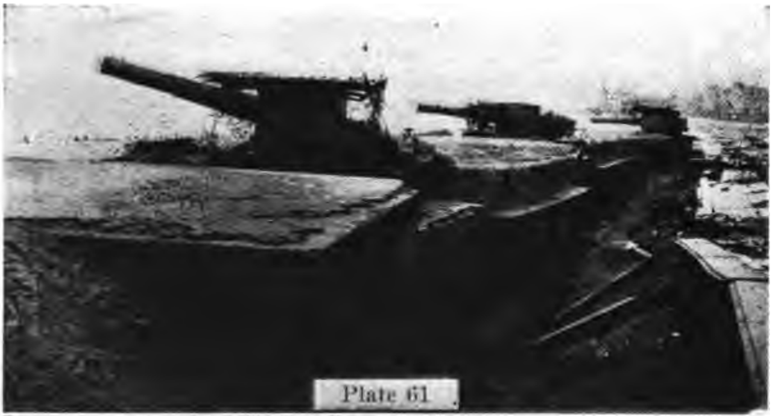
The battery was constructed recently and it is believed that these guns were originally mounted at Battery Antwerpen from which the guns had been removed. It is likely that the exploit of the Vindictive resulted in the construction of the Palace Hotel Battery as it was so located to cover the entrance to the mole.

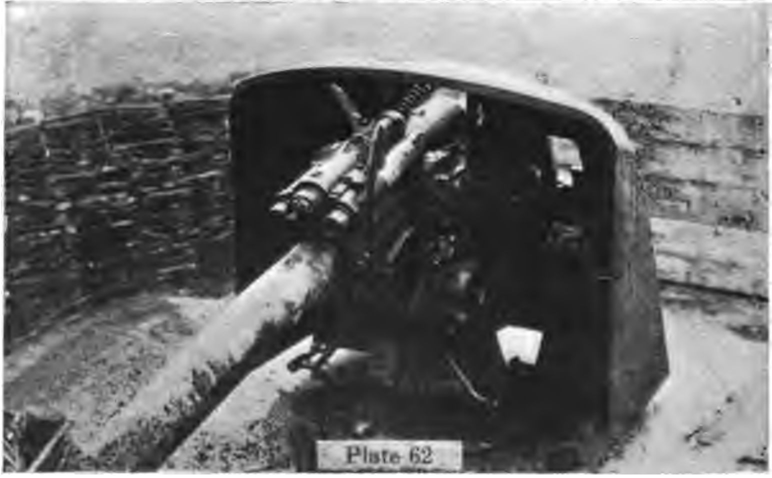
Some brush mats and splotched painting of the guns and shields were the only attempts at concealment.

The gun and carriage were not of recent model. The guns were made in 1904.

The four guns were practically in line but the right flank was bent back so as to increase the arc of fire for the battery. The interval between guns was 30 meters.

Plate 61 will convey some idea of the general appearance of the battery and the type of gun and carriage.





(Top) Palace Hotel Battery, 17-cm. guns. General view of the battery. The fourth piece is not shown in the picture being beyond and to the right of the last piece shown.

(Bottom) Battery Gross Herzog, 8.8-cm. A. A. guns. View of gun and mount.

BATTERY GROSS HERZOG

A four 8.8-cm. gun battery. This battery is typical of these used for anti-aircraft defense.

The gun and carriage are of modern design, the velocity used is 750 m/s with the 10-kg. projectile and 765 m/s with the 9.6-kg. projectile. The gun is 45 calibers in length and the carriage permits an elevation of 70°.

These batteries always comprised four guns arranged in line with very substantial emplacements. The locations were usually found in the vicinity of the non-mobile primary batteries.

Battery Brunhilde

A four 77-mm. gun battery used for anti-aircraft defense. This emplacement was very old and had not been occupied for some time. It is likely that the use of the field gun for anti-aircraft work was discontinued after the emplacement of batteries such as Gross Herzog.

The following plates, Nos. 63 to 73 inclusive are believed to be sufficiently descriptive as to make a separate description for each battery unnecessary

There was nothing of unusual interest in any of these bat-

Plate 63

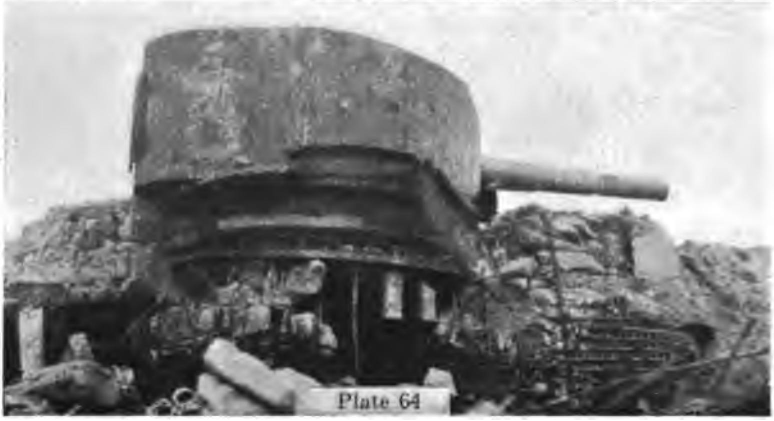


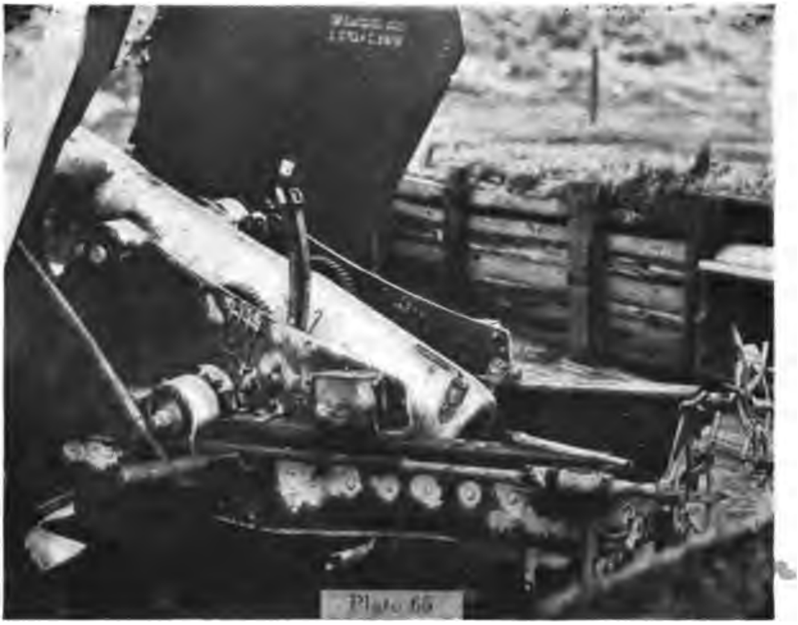
Plate 64

(Top) Battery Goeben, 17-cm. guns. An up-to-date turret battery. These guns carried 12-cm. armor, the thickest found in the coast defenses. The top plates of the turrets were blown off as the result of explosion.

(Bottom) Battery Goeben, 17-cm. guns. A closer view of one of the turrets.

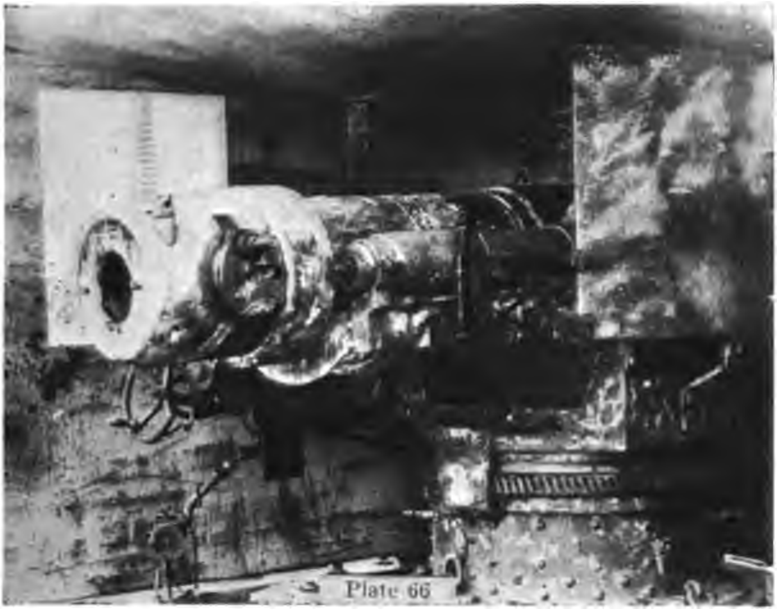
teries pictured. In every case the guns were arranged in line. Except for a variation in model all armament of the same class was of the same type. The battery emplacements varied in detail but nothing unusual was noticed. Magazines were invariably dry.

All of the coast batteries pictured hereafter were located close to the shore and followed the general line of the dunes.



A 105-mm. gun. One of the many odds and ends installed for local defense.

Note the inclined recoil path and the absence of cylinder.



2388

Battery Kaiserin, 15-cm. guns. General view of carriage. Note heavy circular armor plate, peculiar to Naval guns mounted in sponsons. Note the azimuth pointer in lower left hand corner.

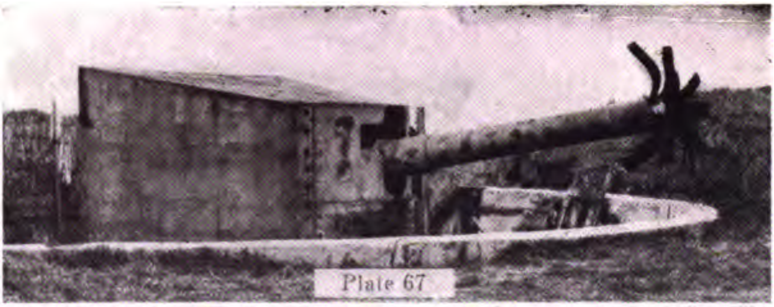


Plate 67

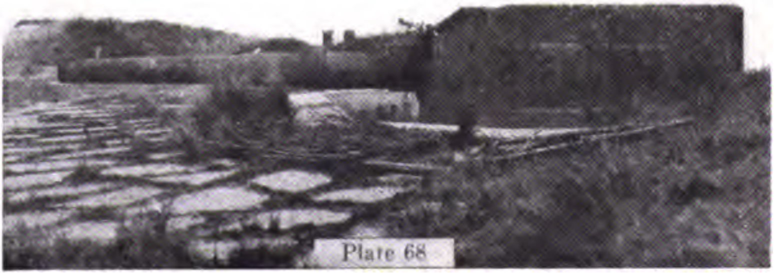


Plate 68

7889

(Top) Battery Kaiserin, 15-cm. guns. One of the guns, showing the effects of bursting a projectile in the gun.

(Bottom) Battery Hertha, 21-cm. guns. General view of one of the turrets. This was one of the most modern of the turret batteries. Note the blast apron, with its suggestion for camouflage by vines growing between the flagstones.

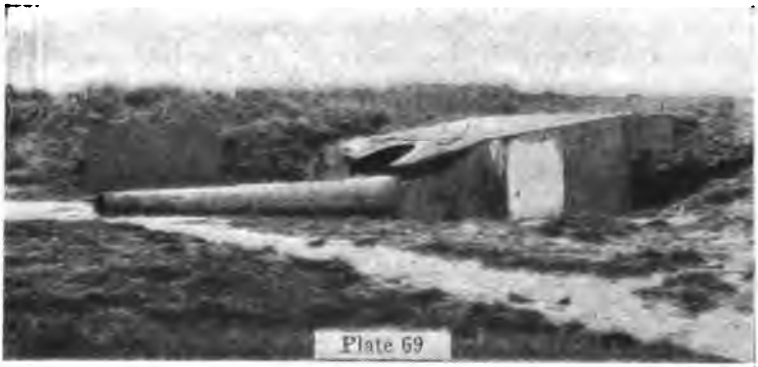


Plate 69

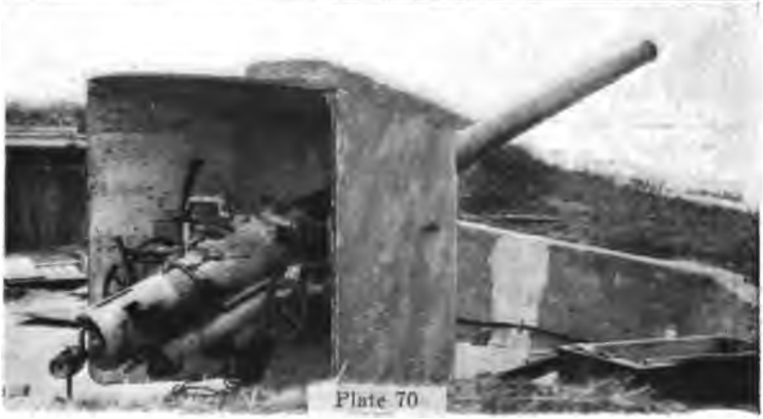
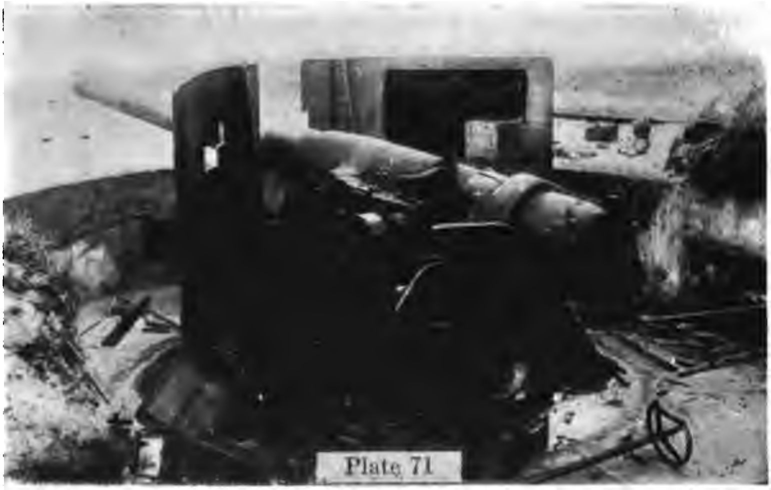


Plate 70

2390

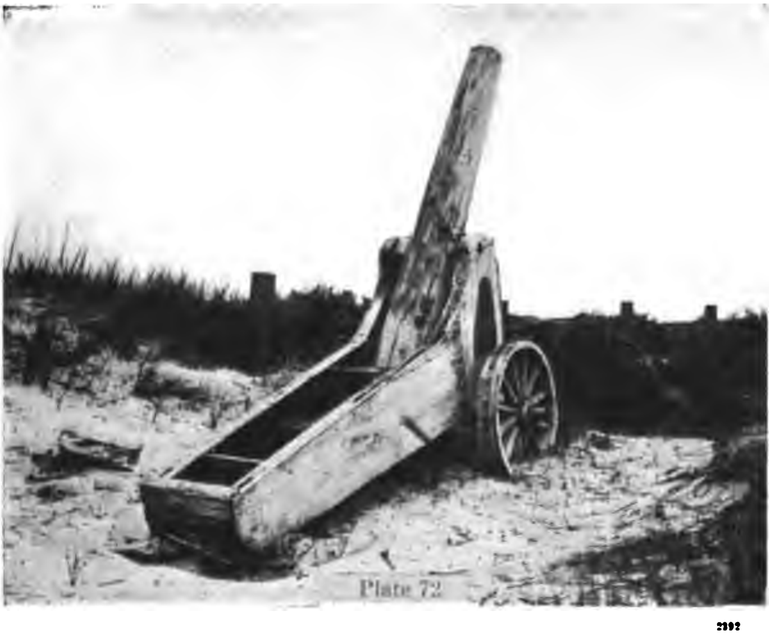
(Top) Battery Cecile, 15-cm. guns. Side view of one of the guns. Note that the shield does not stand out against the sky as a background.

(Bottom) Battery Mittel, 105-mm. guns. Showing the general type of gun in the secondary armament.



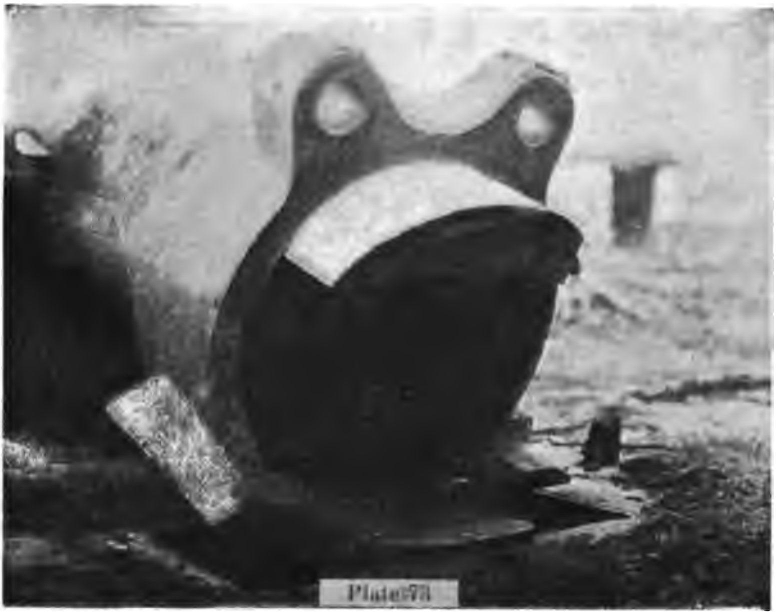
2391

Battery Friedrich, 8.8-cm. guns. General view of gun and mount.



2392

A dummy gun on the Belgian coast.



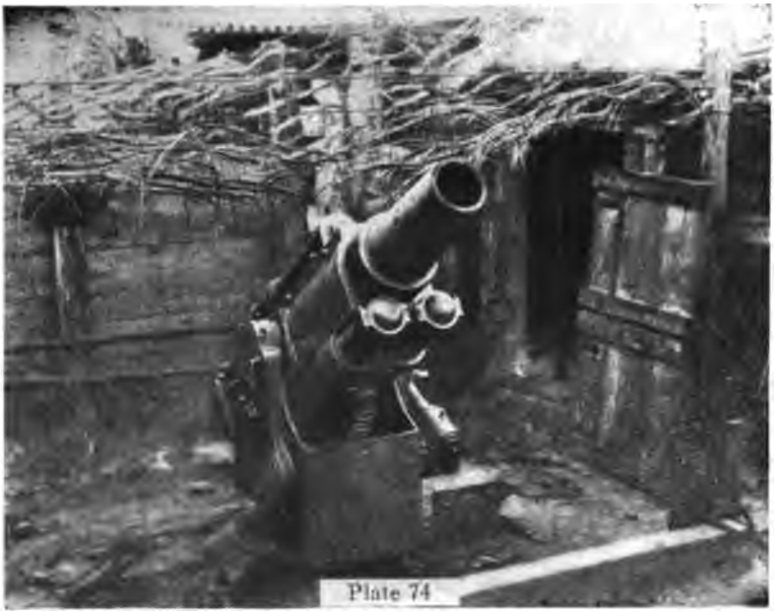
2393

Showing what usually happened to a gun destroyed by the Germans. Exploding projectile in gun was the favorite method.

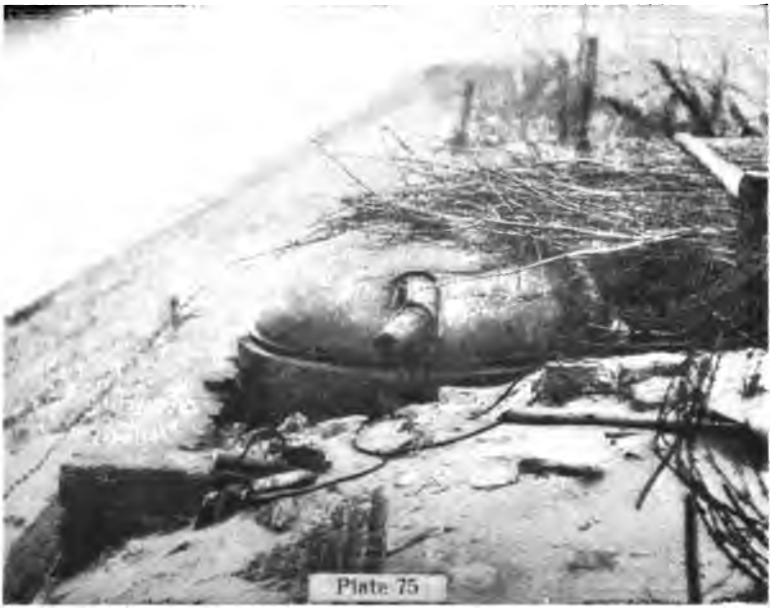
The following plates, Nos. 74 to 76 inclusive, will serve to illustrate some of the artillery used for purely land defense purposes.

Every variety was found from the modern field pieces to the very old Nordenfeldt, five barrel 37-mm. gun. It was not practicable to photograph them all, only the most interesting pieces were pictured.

This land defense artillery was so disposed as to cover attacks from the flanks and rear and to sweep the beaches in the event of landing parties.



A 15-cm. howitzer. View showing general details of the piece.



A 5-cm. turret gun. This like many other pieces of small caliber artillery formed part of the local defense system. Note the sloping sea wall and the barbed wire entanglement extending up the beach.

2896

A 28-cm. howitzer emplacement. View on top and looking down into the embrasure through which the piece fired. This emplacement completely housed the howitzer and contained a magazine, integral with the emplacement.

High Burst Ranging—Adjustment of Artillery Fire by the Tangent Reticule Method*

Second of a Series of three articles

By Lieut. Colonel C. H. Birdseye, C. A.

The tangent reticule method is a form of observation and adjustment of fire by the use of high air bursts. The method is called "tangent reticule" because the instruments employed have a special reticule or subscale in the telescope, the graduations on which can be set to a slope approximately tangent to the trajectory which is being observed.

There are two ways in which this method can be employed; first, to carry out an accurate adjustment on a hidden target, having previously registered on this target by some other form of observation; second, to register on a concealed target without any previous adjustment. The method was designed primarily to solve the first problem but was found to be adaptable to original adjustment of fire and during the latter part of the world war was extensively used for that purpose. The first problem is commonly called the "Referring Adjustment," the meaning of which will appear in the following discussion. The second is known as the "Original Adjustment."

REFERRING ADJUSTMENT

The general principles of this method are as follows: Assume that percussion fire has been adjusted on the target by some other form of observation, such as terrestrial or aeroplane. Select an imaginary point (R), in the air on the trajectory originally found to pass through the target, which can be seen from two observation stations equipped with tangent reticule instruments. Change the original firing data from percussion fire to time fuse fire so as to bring the bursts as near this point as possible. Fire several shots and locate their mean point of burst (C) with reference to the point R. (When resuming fire in the future on this target, use this point C as a registration point). When the new elevation is adjusted so that the trajectory passes through the point C, change back to the original type of projectile and fuse, applying the necessary corrections explained later, and take up percussion fire for effect.

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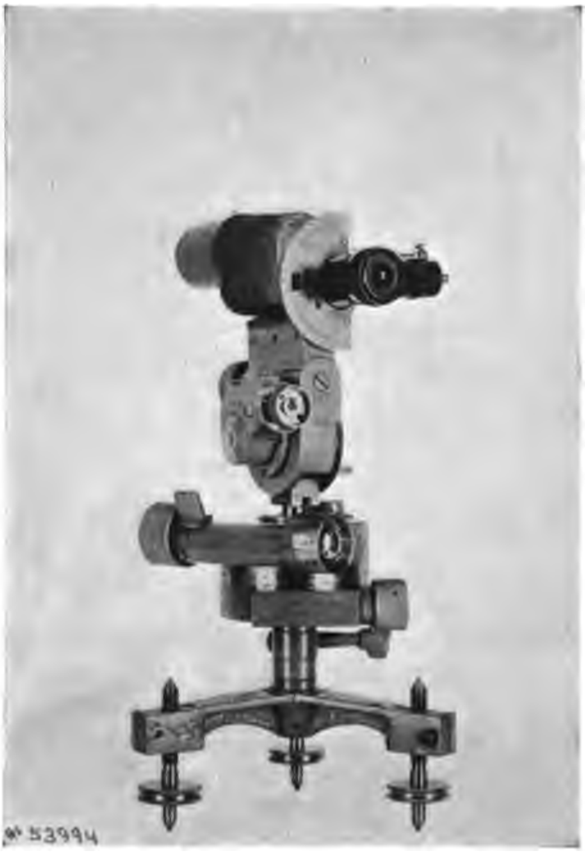
* This discussion of the Tangent Reticule method is largely taken from manuscript prepared at the Heavy Artillery School, A. E. F., by Captain Maurice Barret, French Army.



"U. S. Official" Photo Plate IV 2397

Observation Instruments

A special type of instrument (See Plate IV) is used in which the eye piece, with subscale, can be rotated in a plane perpendicular to the line of collimation. This instrument is properly known as the Rotating Reticule Instrument (Viseur a Micromètre Tournant) but is commonly called the Tangent Reticule Instrument.

It is similar in design to the instrument used for high burst ranging by the Flash Ranging Sections, the only difference being in the graduations on the subscale and in the movement of the eye piece. The subscale is graduated in 5-mil intervals, the zero graduation being in the center and the field of view being 60 mils, 35 mils on either side of the zero graduation (See Fig. 7). The central line, which is vertical when the subscale is in normal position, is also graduated in 5-mil intervals.

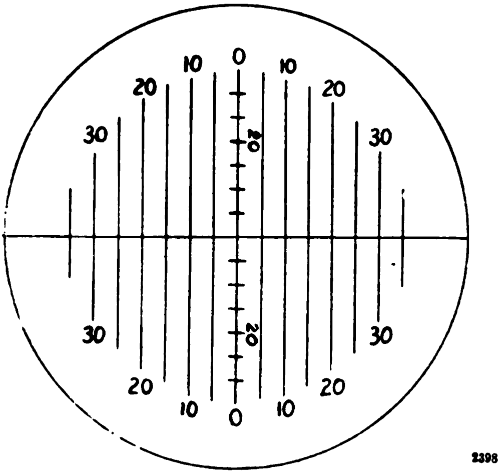


Fig. 7. Subscale in tangent reticule instrument.

An arc graduated in single degrees is fastened to the barrel of the telescope (See Fig. 8). An index, fastened to the eye piece, permits the measurement of the angle of rotation of the subscale. When the index is set at 90 degrees on the arc the subscale is in normal position, i.e., with zero line vertical.

Two observation stations are used, each equipped with a rotating reticule instrument. One of these stations should be near the battery target line so as to give axial observation and the other so placed as to give good intersections on the bursts.

The battery commander first decides how many mils the point of burst (R) should be above the initial plane in order to be visible from both observation stations. This angle (S) should not be greater than 1/8 of the quadrant elevation for the target determined in the previous adjustment. The plane, through the trunnions of the gun, making this angle S with the initial plane is called the reference plane.

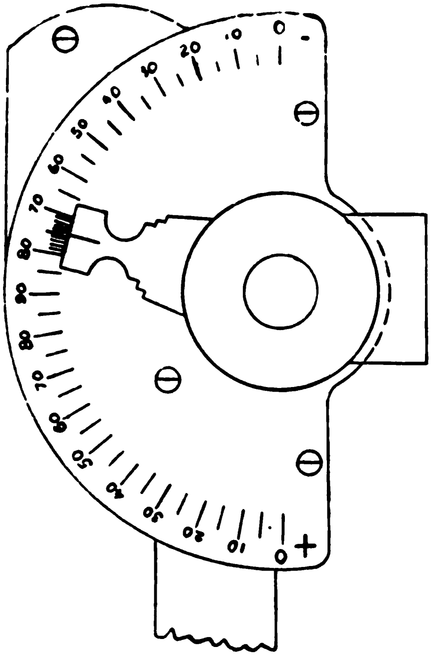


Fig. 8, Arc for measuring rotation of subscale.

He then determines the horizontal projection of the remaining portion of the trajectory, R'F = U (See Fig. 9). The computation of U is based on the assumption that the descending branch of a trajectory, up to about 1/3 of the maximum ordinate, may be replaced by a parabola, with vertical axis through the gun-target line, tangent to the trajectory at the point of fall.

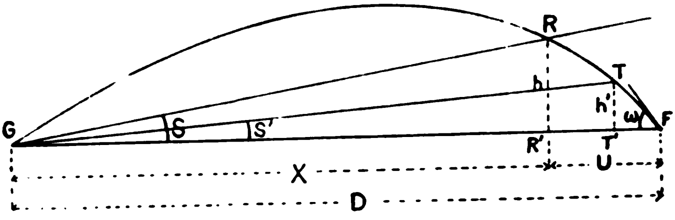


Fig. 9. Vertical projection of the trajectory. 2400

The equation of this parabola is:

$$y = \frac{\tan \omega}{D} (Dx - x^2)$$

At the point R, $y = h = x \tan S$. Substituting this value in the equation above,

$$x \tan S = \frac{\tan \omega}{D} x (D - x)$$

then $U = D - x = D \tan S \cot \omega$

let $K = \tan S \cot \omega$

then $U = KD$

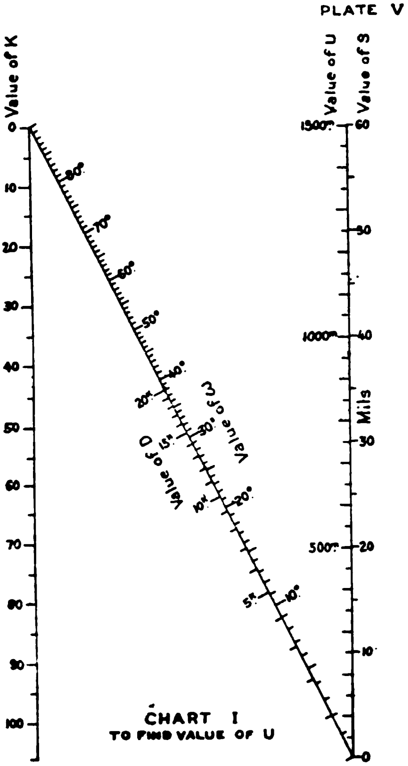


PLATE V

2401

The value of U is generally found by use of Chart I shown in Plate V. This chart is known as an alignment chart or monograph and is designed to solve the particular equation in hand. It is really two charts, superimposed for the sake of convenience and constructed according to certain geometric principles which will not be discussed here. From the proper value of S, on the right hand scale, draw a straight line through the value of ω, on the diagonal scale, to intersect the left hand scale at a value of $K = \tan S \cot \omega$. From this point draw a second line through the value of the range (D) on the diagonal scale to intersect the right hand scale. The value of U is read on the left hand graduations of the right hand scale at this intersection.

If the target is not in the initial plane, the distance $T'F = h' \cot \omega$, where h' is the difference of altitude between target and gun. Then the horizontal distance from the point R to the target is:

$$R'T = U \mp h' \cot \omega$$

according as the target is above or below the initial plane.

The gun-target line (GT) and the point R' are then plotted on a battle map, or on a horizontal plotting board, to the scale of 1 : 20,000. The positions of the observation stations, 0_1 and 0_2 are also plotted and the distance $0_1R' = D_1$ and $0_2R' = D_2$ are scaled from the plot. The angles $GR'0_1 = b_1$ and $GR'0_2 = b_2$ and the Y-azimuths of the lines $0_1R' = V_1$ and $0_2R' = V_2$ are also measured graphically.

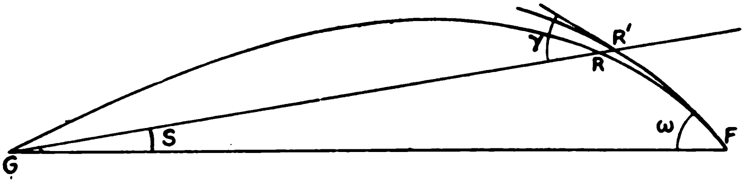


Fig. 10. Vertical projection of trajectory and parabola. 2402

The angles of site in mils from the observation stations to the point R are given by the formulas;

$$S_1 = \frac{1000\ h_1}{D_1} \qquad S_2 = \frac{1000\ h_2}{D_2}$$

The next step in the procedure is the determination of the angle (I) at which the reticule of the instrument should be set so that the zero graduation on the subscale will be tangent to the trajectory at the point R. This involves finding the trace of the tangent to the trajectory at R on the plane of the subscale of each instrument.

The tangent to the true trajectory at the point R is replaced by the tangent to the parabola at its intersection with the reference plane. The angle (See Fig. 10), which this tangent makes with the reference plane is found by the following empirical formula based on firings by the French Artillery:

$$\tan \gamma = (1-1.2K) \tan \omega$$

Consider the tetrahedron in Figure 11 formed by the vertical plane through the BT line (MNR), the plane of the subscale (MNO), the plane defined by the line GR and the line OR (MOR), and the plane defined by the optical axis of the instrument and the zero graduation on the subscale when parallel to the trajectory (NOR).

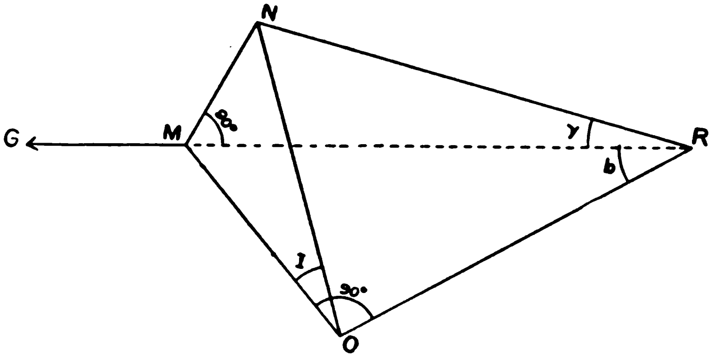


Fig. 11. Tetrahedron formed by planes intersecting at R. 2403

$$\begin{aligned} MN &= MR \tan \gamma \\ OM &= MR \sin b \\ \tan I &= \frac{MN}{OM} = \frac{\tan \gamma}{\sin b} = (1-1.2K)\frac{\tan \omega}{\sin b} \end{aligned}$$

In Figure 12 the observation station O_1 is on the GT line, consequently $I_1 = 90$ degrees and the trace of the tangent is a vertical line. The line O_2R' is perpendicular to the GT line and $\tan I_2 = (1-1.2K) \tan \omega$. If the angle of site (S) is small so that R is close to the initial plane, I_2 is approximately equal to ω. Station O_3 is to the right of the GT line and the inclination is measured from the left towards the vertical. Section O_4 is to the left and the inclination is measured from the right towards the vertical.

The index on the eye piece of the instruments (See Fig. 8) is so arranged that it reads 90 degrees when the zero graduation on the subscale is in a vertical position. Consequently when the observation station is to the right of the GT line the index will be set below the 90 degree graduation, and when to the left it will be set above. Angles to the right of the GT line are considered positive and to the left negative.

The value of the inclination is usually found by use of Chart 2, shown in Plate VI, which is similar in principle to Chart I. From the value of K on the right hand scale, draw a straight line through the value of ω on the diagonal scale to intersect the left hand scale; from this point draw a second line to the value of b on the right hand scale. The value of I is read at the point where this line intersects the diagonal scale.

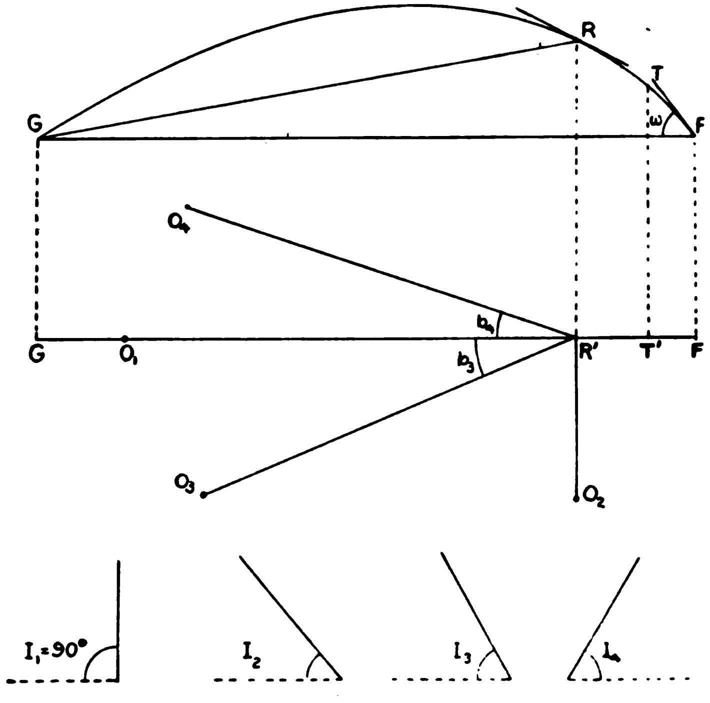


Fig. 12. Inclination of graduations on the subscale. 2404

PLOTTING BURSTS

The plane of sight formed by the optical axis of the instrument and each graduation on the subscale intersects the reference plane in a line making an angle, in the reference plane, from the line GR equal to b. When a burst is observed on one of these graduations, its trajectory pierces the reference plane somewhere along the line of intersection of the plane of site of that particular graduation with the plane of reference.

When a burst is observed from two stations, the point where the trajectory pierces the reference plane is at the intersection of the two lines representing the intersections of the two planes of sight with the reference plane (See Fig. 13). This point (I) is called the imaginary point of impact.

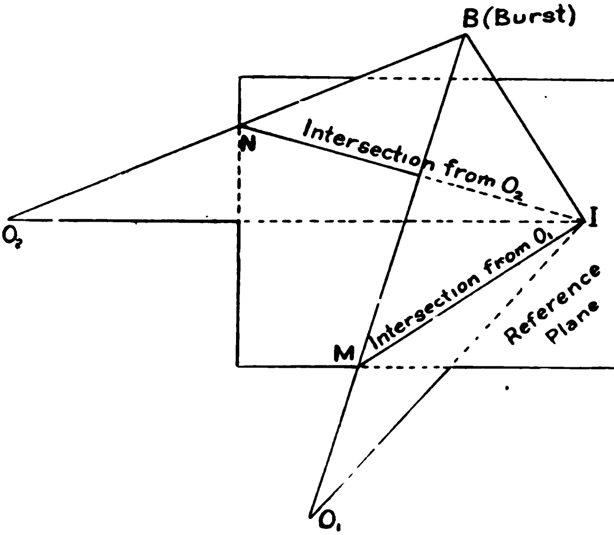


Fig. 13. Intersections of planes of site with reference plane. 2405

Thus we have on the reference plane an imaginary network of lines representing the intersections of the planes of sight corresponding to each graduation on each subscale. For all practical purposes the lines corresponding to each subscale may be considered parallel and equidistant. The angle between the lines corresponding to the two subscales is equal to the horizontal angle $O_1RO_2 = b_1 + b_2$. The spacing between the lines is a function of the distance from the observation station to the point R and of the inclination of the lines.

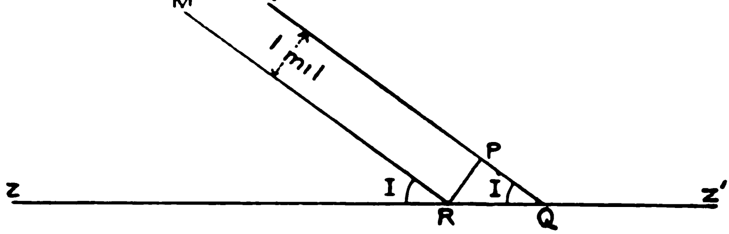


Fig. 14. Spacing of lines on fire diagram. 2406

In Figure 14, the surface of the paper represents a plane through the point R, parallel to the plane of the subscale. The line ZZ′ represents the trace of the plane of reference on this plane and the lines RM and QN represent the intersections of two planes of sight differing by 1 mil. The interval $RP = \frac{D}{1000}$ and is projected on the reference plane as $RQ = \frac{RP}{\sin I}$ therefore;

$$RQ = \frac{D}{1000 \sin I}$$

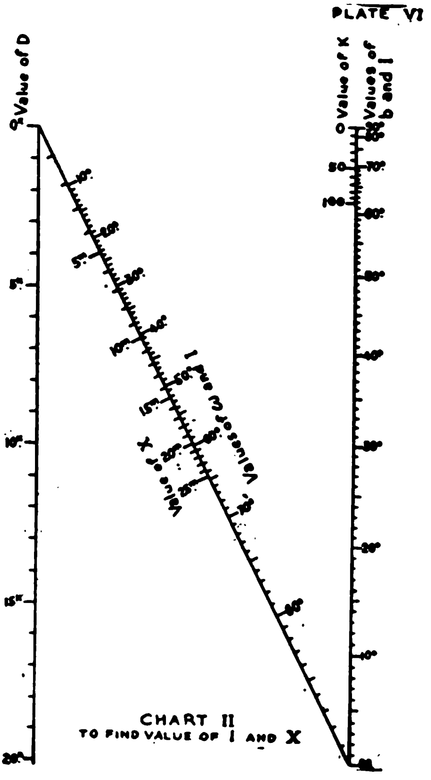


Plate VI

Let the spacing in meters for O_1 be represented by X_1 and for O_2 by X_2. Let the distance O_1R in kilometers be represented by D_1 and O_2R by D_2.

then $X_1 = \frac{D_1}{\sin I_1}$ $X_2 = \frac{D_2}{\sin I_2}$

The value of X may be found from Chart 2 in Plate VI. From the value of D on the left hand scale draw a line to the value of I on the right hand scale. The value of X is read on the diagonal scale at the intersection with this line.

A chart called a *fire diagram* (*Graphique de Tir*) is prepared reproducing these lines on the reference plane to a convenient scale, usually 1 : 5000 (See Fig. 15).

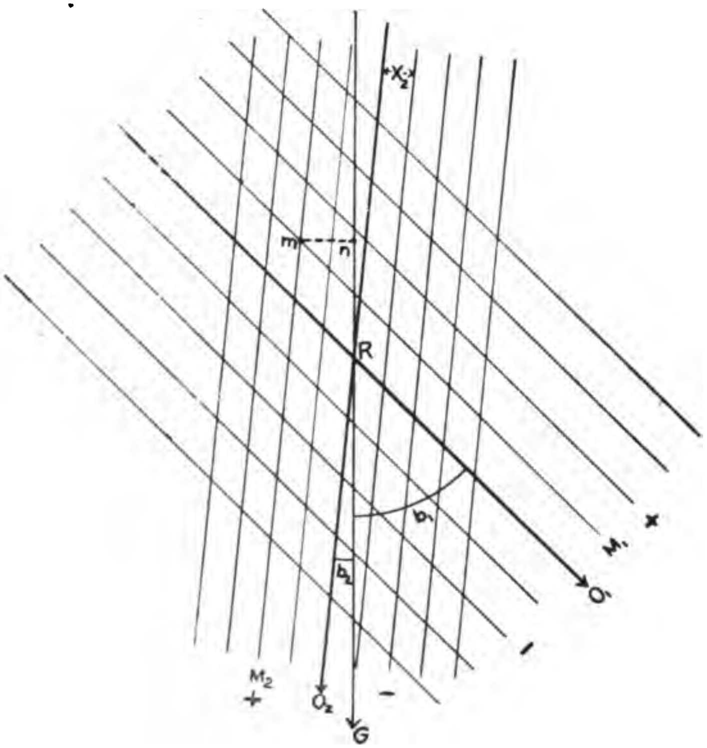


Fig. 15. Fire diagram. 2408

The center line represents the vertical plane through the GT line. The lines O_1R and O_2R represent the intersections of planes of sight through the zero graduations on the subscales of O_1 and O_2 respectively. The lines representing the other graduations are drawn parallel to O_1R and O_2R and spaced to scale according to the proper multiples of X_1 and X_2.

The fire diagram is then complete. If a burst is observed at O_1 on the graduation $+M_1$ and at O_2 on the graduation $+M_2$, the imaginary point of impact of this shot is located at m and the deviations from R are Rn over, nm left.

Execution of the Firing in Detail

The Referring Fire

During the original fire for adjustment the Battery Commander fills in the data sheet (See pages 202 and 203) and sends instructions to the high burst observers. As soon as the adjustment is complete and the observers are ready they call for one or two high bursts.

Each observer brings the zero of his reticule on the burst. To do this he swings the telescope if necessary, altering the reading of the horizontal limb. Each observer reports his new reading to the Battery Commander. These angles, corresponding to the gisements of the bursts, are called V_1 and V_2.

Having once reported them they must not be changed. At the same time the axial observer notes the height of burst above the horizontal diameter of his instrument and reports it to the Battery Commander. This is called f.

It is desirable to have the bursts as nearly as possible in the center of the field of each instrument. For this reason the Battery Commander must correct the fuse setting by an amount equivalent to the angle f reported. This may be accomplished by use of the Time of Flight Chart (See Plate III in June installment). If the burst is too high by f mils it should be lowered by $\frac{fD_1}{1000}$ meters. Pick out the trajectory on the chart which corresponds to the elevation used. Obtain the point R on the trajectory at the altitude h (See Fig. 16). Scale off a vertical distance RP equal to $\frac{fD_1}{1000}$ and draw a horizontal line PQ. Convert the line interval (t′−t), read on the curves of equal time of flight, into fuse setting. This

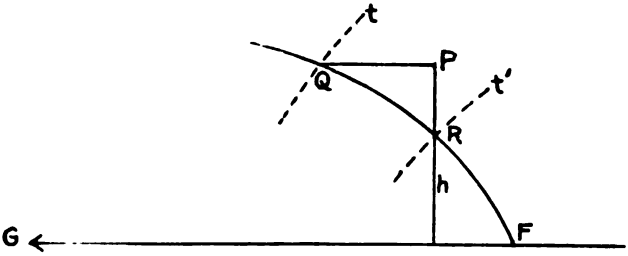


Fig. 16. Correction to time of flight. 2403

gives the correction to bring the burst down to the center of the observers' field of view.

After the fuse correction has been made a salvo is fired at 10 or 15 seconds interval. Each observer reports the deviations as read on his reticule, and the axial observer reports the height of burst of each shot. The battery commander plots the shots on the fire diagram. In order to eliminate the effect of any error in the inclination of the reticule graduation lines, due to the fact that they are not actually tangent to the trajectory, it is desirable to have a mean point as nearly as possible on the center line of the two reticules. This corresponds to a burst in the reference plane. To accomplish this the battery commander alters the fuse setting for the second salvo to bring the bursts on the opposite side of the horizontal diameters of the observers' reticules from the first set. The deviations of the second salvo are reported as before. The battery commander plots the mean point of the two salvos on the fire diagram.

The mean point may be called C and is known as the *characteristic* of the referred adjustment. It becomes then a registration point in the air. The mean readings of the two reticules, M_1 and M_2, are recorded on the data sheet.

To Resume Fire on the Same Target Without Direct Observation

The Battery Commander computes the data to give a converging sheaf on the target. The same type of projectile and fuse must be used as in the referring fire in order that the conditions of passage from the resuming fire to the percussion fire may be the same. The powder need not be of the same lot or the same charge. The data S_1, S_2, V_1, V_2, I_1, and I_2 are sent to the observers. One shot is fired. The observers report the deviations and the shot is plotted on the fire diagram. The Battery Commander then computes the range and deflection corrections to bring the trajectory through the point C. He also adjusts the fuse setting to center the bursts in the field of view of the instruments. Then a salvo of 4 shots is fired and each shot and the mean of the salvo is plotted. Similar corrections are again computed for this mean point and two salvos are fired on the new data. The mean point (C_1) is plotted and the range and deflection corrections between C_1 and C are scaled from the plot.

If the deviations of the first salvo are less than 50 meters in deflection and 100 meters in range do not correct this data before the next salvo. The fuse setting, however, should be adjusted if necessary. In this case one more salvo is sufficient to complete the resuming fire. Corrections for individual guns may also be required in such a case.

Residual Correction

Owing to a change in the form of the trajectory due to changing atmospheric and ballistic conditions, the elevation found by the above corrections may not actually reach the target. The ultimate correction for this change in form, called the residual correction, is shown in Fig. 17. In reality it is two corrections, the residual correction proper and the difference between $h' \cot \omega$ for the two trajectories. In the original directly observed adjustment the trajectory GRT hits the target T, and cuts the horizontal plane through the muzzle of the gun at F. In the resuming fire the trajectory changed its form to GRT′, passing through the point R but falling at T′, short of the target by the amount TT′, and cutting the initial plane at F′. If the trajectory is adjusted to pass through F, it will hit at T″, over the target by the amount TT″.

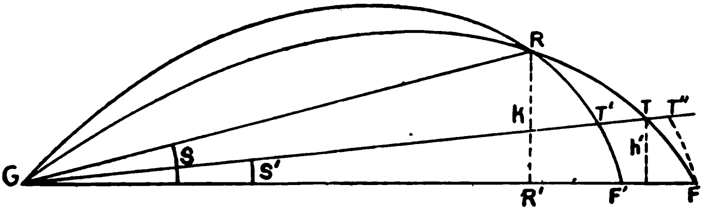


Fig. 17. Residual correction. 2410

TT″ is the difference between $h' \cot \omega$ and $h' \cot \omega'$, ω and ω' being the angles of fall for the adjusted fire and the resuming fire respectively. The total residual correction (T′T) as shown in Fig. 17 will be $R'F - R'F' - (h' \cot \omega - h' \cot \omega')$. Where ω' is greater than ω, the correction $R'F - R'F'$ is positive, and vice versa. If T is above the horizontal plane through G, $h' \cot \omega - h' \cot \omega'$ with the proper sign is subtracted from $R'F - R'F'$; if T is below the horizontal plane, it is added.

Chart 1 may be used to obtain the values of $h' \cot \omega$ and $h' \cot \omega'$. Let S' equal the angle of site of T from G, ω the angle of fall of the original adjusted elevation, and D the map range to T. From the value of S′ on the right hand vertical scale draw a line through the value of ω on the diagonal scale until it intersects the left hand vertical scale. From this point draw a line through the value of the map range on the diagonal scale, to the right hand scale and read the value of U. Perform a similar operation for ω'. We now have two values, U and U′. Their difference, $U-U'$, is $h' \cot \omega - h' \cot \omega'$.

The values of R′F and R′F′ are found in the same way by use of Chart 1, taking S equal to the angle of site of the reference plane, ω and ω' as the angles of fall, and D as the map range to the target. To be strictly accurate the ranges GF and GF′ should be used instead of simply the map range, but this substitution will make little difference in the value of $R'F-R'F'$.

No residual correction is necessary if the two angles of fall differ by less than 2 degrees. The residual correction in direction is always negligible.

Calibration of Guns

Using any range D, carry out a fire as explained above, using 6 battery salvos as a minimum. Plot the mean point for each gun on the fire diagram. Refer the results of the other three guns to the newest gun. The range corrections thus found can be corrected into a dV_0 variation.

Comparing Powder Lots

Follow the same principles as laid down in the last paragraph. Use one gun with the two different lots, and compare the range differences.

In both of the above cases a residual correction must be applied if the angles of fall vary by more than 2 degrees.

Special Cases

With high velocity rifles having a low trajectory, in order to have the bursts high enough to be visible, it might be necessary to time them near the summit of the trajectory. This would take them too far back from the target to give reliable results and, with targets near the front lines, would endanger friendly troops.

In such cases the elevation should be increased by a certain amount, $S-S'$, (See Fig. 18), in such a way that a burst in the reference plane will be visible. Direct the instruments on the point R, the intersection of the plane with angle of site S and the vertical through the target. Take the fuse setting corresponding to a zero height of burst (i.e., the fuse setting given in the range table that would cause the shell to burst just before reaching the target,) and correct it for the increased elevation as explained for referring fire. When resuming fire, after the adjustment on the point R is completed, drop the elevation by S−S′.

Original Adjustment by the Tangent Reticule Method

In this case no previous adjustment has been made on the target. The battery is to be adjusted by firing on a fictitious point in the air, the bursts being located by the rotating reticule instruments. This fictitious point must be located by computation. The topographic preparation must be very carefully carried out from reliable data. The observing instruments must be accurately oriented.

There are two methods of effecting the adjustment: first, with the point of adjustment on the vertical line through the target; second, with the point on the trajectory that would pass through the target.

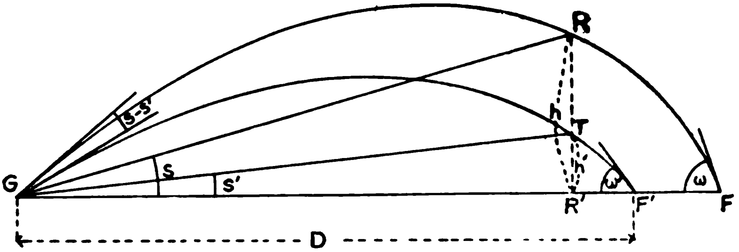


Fig. 18. Adjustment on point directly over target.

Point of Adjustment on the Vertical through the Target (Fig. 18).

Select a fictitious registration point (R) on the vertical line (TR) passing through the target, with an angle of site (S) sufficient to allow the bursts to be seen. The height of the point R above the initial plane is given by the formula $h = \frac{DS}{1000}$, in which S is expressed in mils. From the value of h the angles of site from the observation stations to the point R can readily be computed. The usual method is carried out for registration on the point R. When the adjusted range on R is secured, it must be dropped to the proper site for the target by decreasing it by $h \cot \omega - h' \cot \omega'$, ω being the angle of fall for the trajectory passing through R and ω' for the trajectory passing through T. To change to percussion fire a correction must be made for the different fuse.

Point of Adjustment on the Trajectory which would pass through the Target

The Battery Commander computes the elevation necessary to reach the target taking into account all the corrections of the moment. The angle S is selected as described in the referring adjustment.

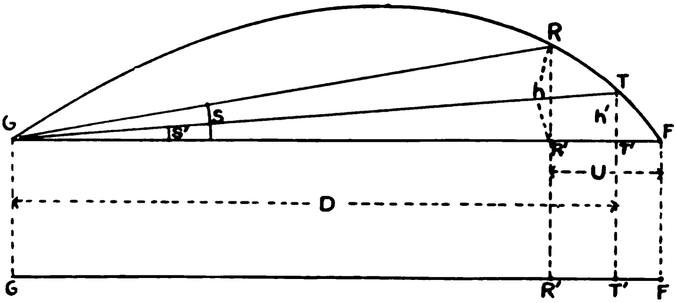


Fig. 19. Adjustment on the true trajectory.

The distance R'F = U (See Fig. 19) may be found from Chart I, using as arguments the angle S and the range table value of ω. The distance T'F can be found from the same chart using S' instead of S or, if small, by the formula $T'F = h' \cot \omega$. Then the point R' can be plotted with reference to the Point T' by use of the following equation:

$$R'T' = U - h' \cot \omega$$

The fire is then carried out on the fictitious registration point R as previously described. As the range to R(GR') is shorter than D(GT'), the effect of wind and drift will be less for the adjustment than for the fire for effect. This difference must be computed in figuring the final deflection. A correction must also be made for fuse when changing from to percussion fire.

ADVANTAGES OF THE METHOD

In general, under either the referring adjustment method or the original adjustment method, the advantages of the Tangent Reticule Method may be summarized as follows:

(a) The accuracy is good. The variation in resuming fire should be less than 1 probable error, provided no time is lost in changing from percussion to time fire and vice versa.

(b) Accurate topographic and meteorological data are not necessary when using the referring method.

(c) A new unit, with the same type of guns, can adjust at once by using the data of the old unit.

(d) Fire for effect can be kept adjusted by occasional air bursts. This relieves for other duties the aeroplane which has been used for direct adjustment.

(e) The method permits direct adjustment on captive balloons.

(f) It can be used with defiladed observation posts.

(g) It can be employed by night or day.

(h) It permits registration when no suitable registration point can be found on the ground.

(i) It can be employed by the personnel of the battery or battalion.

(j) In the referring adjustment method errors due to changing from percussion to time fuses and vice versa, are eliminated, as the change for the referring fire is exactly reversed in resuming fire.

(k) The results are not dependent on accurate functioning of the time fuses.

LIMITATIONS OF THE METHOD

(a) Referring Adjustment Method.
  (1) Good visibility is required in order to see the bursts.

(b) Original Adjustment Method.
  (1) Good visibility is required in order to see the bursts.
  (2) Accurately located observation posts and very accurately orientated instruments are necessary.
  (3) Accurate co-ordinates of the target are required.
  (4) The method is not reliable enough for precision fire. Fire on a narrow zone is advisable, the limits being for example 100 meters in range and 3 mils in direction for ranges between 10 and 15 kilometers.

EXTRACTS FROM A REPORT OF A BOARD OF OFFICERS CONVENED AT CAMP SOUGE, FRANCE, TO CONDUCT TESTS OF HIGH BURST RANGING BY THE TANGENT RETICULE METHOD

The first test was conducted on September 11 and 12, 1918, with a 75 mm. gun, normal charge shell, and combination double effect time fuse, Model 1916. On September 21, three other tests were conducted with same gun, shell and fuse, but with reduced charge.

In detail the tests were as follows:

Test No. 1

On September 11 the fire was adjusted on a target by terrestrial observation, and then referred to a fictitious witness target along the mean trajectory. On September 12 the fire was again resumed and adjusted on the fictitious witness target of the day before, and later on the original target on which fire for effect was delivered. The mean point of impact was found to be 1-2/3 probable errors beyond the target, the direction being correct. The fire was held up on frequent occasions throughout the test because of bad weather conditions, and a considerable period of time elapsed between the adjustment on the target and the referring on the fictitious witness target. Part of the error was probably due to a change in weather conditions during this time.

Test No. 2

The second test was conducted on September 21 and was identical with the first, except that a different target and a different powder charge were used. The adjustment on the target was conducted in the morning, and the firing was resumed in the afternoon. In the fire for effect, the mean point of impact was found to be 1/5 of a fork or 13 meters beyond the target. About 20 minutes elapsed between the end of the adjustment on the target and the completion of the referring on the fictitious witness target, during which the weather conditions may have changed slightly, as seemed to be the case by the fact that three rounds fired on percussion, after the referring, were all distinctly over the target.

Test No. 3

The test included the direct registration on a computed fictitious auxiliary target directly above the target to be fired upon, no previous adjustment having been made on the target itself. In fire for effect, the mean point of impact was

2 meters short of the target, 5 shots falling short, 3 shots over, and 2 shots being direct hits.

Test No. 4

This test included the registration on a computed fictitious auxiliary target on the trajectory passing through the target, and later fire for effect on the target. In the fire for effect the mean point of impact was found to be 9 meters beyond the target. Out of the 10 shots fired, 7 were over and three were direct hits.

The tests on September 21 were conducted under very favorable conditions. The target was practically on the same level as the gun, thus eliminating the question of the difference in the correction "h cot ω" for the two trajectories. A small gun, the 75 mm., was used. With the light artillery this correction is not so important as with the 155 G.P.F. and heavier guns. Furthermore the nature of the terrain permitted the bursts to be brought down very close to the target thus making any error in the residual correction very small.

The following Data Sheets illustrate the procedure in an adjustment by the referring method.

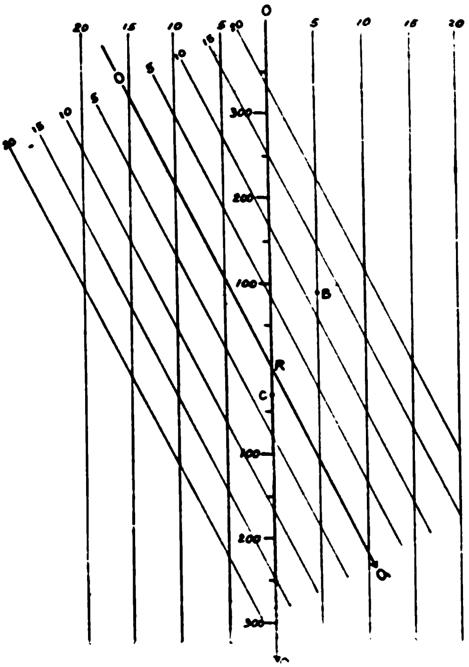


Fig. 20. Fire Diagram for problem in data sheet. 2413

DATA SHEET NO....
(Referring Adjustment ,Tangent Reticule Method).

Battery........................ Target........................ Date..................

Caliber	155 GPF
Projectile	FA Shell
Percussion fuse	IAL
Time fuse	LD
Charge	1

	Coordinates		Altitude
	X	Y	
Battery	....	....	....
Target	....	....	....
O₁	....	....	....
O₂	....	....	....

Deflection	212 mils
Adjusted Elevation (E)	18°
Adjusted ω	30°

Range to target	(D)	12,000 mils
Elevation	(E)	19° 50′
Angle of fall	(ω)	32° 30′
Site of point R	(S)	40 mils
Elevation coefficient	(K)	63 mils
Interval R′T′	(U)	750 mils
Range to Point R	(GR′)	11,250 mils
Observation distances	(D_1)	6000 mils
	(D_2)	10,750 mils
Observation angles	(b_1)	+27°
	(b_2)	0°

Angles of Site	Battery to Target	(S′)	17 mils
	O₁ to R	(S_1)	58 mils
	O₂ to R	(S_2)	37 mils
Inclination of reticules	O₁	(I_1)	54°
	O₂	(I_2)	90°
Y-azimuth of lines	O₁R	(V_1)	1025 mils
	O₂R	(V_2)	1500 mils
Mean reading on subscale	O₁	(M_1)	Left 2
	O₂	(M_2)	0
Spacing of lines on fire diagram	O₁	(X_1)	7.5 mils
	O₂	(X_2)	11.0 mils

DIFFERENCE OF ALTITUDE

R and Battery	(h)	450 mils
R and O₁	(h_1)	350 mils
R and O₂	(h_2)	400 mils
Target and Battery	(h′)	+200 mils

REFERRING FIRE

Fuse Setting	33.2″
Correction for change of 100 meters in height of burst	0.9″

RESUMING FIRE

Initial Elevation 22° 30′ Deflection 215 mils

Fuse Setting	39.6″
Correction to Elevation for change of 100 meters in range	21′
Correction to fuse setting for change of 100 meters in h	0.8″
Correction to fuse setting for change of 1° in Elevation	1.3″

DATA SHEET, (Continued).

Shot No.	Gun No.	V	Elev.	Fuse Set.	M_1	M_2	f	REMARKS
1	1	212	18°	33″.2	0	0	+5	As the burst was +5 mils as measured at O_2, it is 5x11 = 55 meters above the reference plane. Increase fuse setting by .55x0″.9 = 0″.5
2	1	212	18°	33″.7	0	0	+3	The mean f is +2. The bursts must be lowered 4 mils, or 44 meters, to bring them on the opposite side of the reference plane by −2 mils. Increase fuse setting by 0″.4.
3	2				R 1	0	+2	
4	3				L 2	0	+2	
5	4				L 3	0	+1	
6	1	212	18°	34″.1	L 1	0	−1	M_1 for the mean point C is L 2, M_2 is 0 C is plotted on the Fire Diagram. The referring fire is now completed.
7	2				L 8	0	−3	
8	3				L 5	0	−2	
9	4				R 3	0	−4	

RESUMING FIRE

Shot No.	Gun No.	V	Elev.	Fuse Set.	M_1	M_2	f	REMARKS
1	1	215	22°30	39″.6	R 12	R 5	−6	Correction: Left 5, - 125 m. or - 25′. (See point B on Fire Diagram.) Fuse setting for change in elevation is 39″.6 − 25/60x1.3 = 39″.1. The burst is −6 mils or −66 meters. Fuse setting is 39″.1 − .66x0.8 = 38″.6.
2	1	220	22°05	38″.6	R 5	0	+3	Center of Impact is 0,0. No correction. Fire one salvo to complete the Resuming Fire.
3	2				R 7	0	0	
4	3				L 7	0	−2	
5	4				L 7	0	+1	
6	1	220	22°05	38″.6	R 10	0	0	Center of Impact, C_1, of the two salvos is R 1, 0. $C_1 - C$ = +45 m. (See Fire Diagram). Decrease elevation by 10′ to 21°55′. ω′ for 21°55′ = 35°20I. ω for 18° (Referring Fire) = 30°, h′cot ω = +350 m. h′ cot ω′ = +280 m. (Chart II) R′F (for 18°) = +825 m. R′ F′ (for 21°55′) = 670. Total Residual correction = 825 − 670 − 70 = +85 m. or +18′. Final adjusted elevation = 21°55′ + 18′ = 22°13.
7	2				R 1	0	−3	
8	3				R 2	0	−2	
3	4				L 3	0	+1	

EDITORIAL REVIEWS

REWARDS

In these days of uncertainty as to the future of the Army, it is natural that the minds of regular officers should be invaded with the query whether the game is worth the candle, whether the rewards of the service will compensate them for their future initiative and the expenditure of professional effort. The atmosphere is depressing, as in dog-days, heavy with the fog of uncertainty. Many wait, with anxiety but with not too much confidence, for a refreshing gale of legislative enactment to sweep away the present cloud of uncertainty and stagnation. A rational consideration of former cycles justifies the reflection that the tide of activity and progress now at low ebb from its tumultuous torrent of the tremendous months of the war, will gain momentum and swell again, coursing the new channels of a deeper, wider system of national defense; sweeping clean the present pool of stagnant reaction with a fresh current of enthusiasm and progress.

But even now, with no presaging ripple of a new flood tide, there is within the reach of every officer the sound reality for satisfaction in the effort in which he shares, and for a reasonable contentment with that effort's reward. The business of being an officer is essentially a *profession*, with all that the term connotes of mental activity, of humanist outlook, of unselfish purpose. Now it is well recognized that the material rewards of the professions are inferior to the material rewards of commerical industry. The professional man foregoes a place in the race for wealth in behalf of the opportunity for recognition among his professional fellows of his attainments and usefulness in a chosen field. If he but command a comfortable competence for the decent support of himself and his family, he accepts as the proper reward for his life's work the fellowship and respect of others engaged with him in a special field, whose standards and usefulness may not be understood by those without the pale of the profession. So keenly is this attitude sensed in the military profession that the true-hearted soldier scorns meretricious publicity and the leverage of external notoriety to hasten his advancement. For he knows full well that the enduring satisfactions ripening with the years of his service, come only from the recognition and respect accorded him by his associates, who alone can appraise his worth and the value of his work.

Perhaps in gray days and dark hours do the virtues of calm determination and undismayed effort glow most brilliantly. If these times be dull in promise, then will the contagion of optimism in military comradeship be most refreshing.

The real reward of military service is the compounding capital of respect which an officer may earn from his fellows. Now—pre-eminently now—is a time when the funding of that reward may be uncommonly multiplied by him whose conviction in the worth-whileness of his calling is confirmed and unboundingly overflows.

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THE RIGHT MAN ON THE RIGHT JOB

A question often heard from young officers fresh from business life, and sometimes from older officers is—"Why won't the army let an officer specialize, and fit the right man to the right job?" The question deserves a thoughtful answer, and one answer is, the army *does* let an officer specialize. Every arm of the service represents a distinct specialization of the functions of an army. Again, within each arm of the service some officers, more skilled in certain kinds of work, have always been called upon to handle the problems requiring such especial skill. During the war, as a measure of necessity, specialization was carried to extremes. There were Infantry officers, trained and commissioned for the emergency, who knew little but hand grenades and how to instruct others in their use. There were Field Artillery officers who knew little but horse-training and stable management. There were Coast Artillery officers who knew little but the operation and repair of motor transportation. Obviously, such officers were needed with an intensive knowledge in a limited field. Quite as obviously, these officers did not have the sweep of outlook over the whole game to exercise command of larger units or to co-ordinate extended tactical or technical activity.

It is to be hoped that the army will confront its next emergency better prepared, so that makeshift measures will not need to be resorted to. This will mean that a sufficient reservoir of trained officers will have been made available so that officers may be had for every duty who yet have a breadth of experience and tactical conception which is not circumscribed by the narrow limits of some mechanical specialty.

During the progress of a great war casualties will be so heavy and expansion so great that rapid promotions will be a foregone conclusion. This war-time promotion of professional officers, old and young, will thrust them into positions of command and executive control whose responsibility will transcend any responsibility demanded of them in peace-time service. Their duties in peace-time must prepare them in the most conscious manner for enlarged responsibilities in war. One very direct way of meeting this end is to shift an officer from one detail to another, leaving him in one position just long enough to learn the work and then accomplish some effective results in it. Only in some such manner can an officer acquire the breadth of view by which he may balance conflicting demands presented to him in the administration of an important position in war.

However, this scheme of things predicates the assumption that all line officers can be fitted for extensive tactical and executive responsibility. Such an assumption is in fact unwarranted. Passing by the indifferent and incompetent classes among officers, there are yet others of industry and ability who are fitted by nature for greater usefulness in some other field than that of command. For instance, there is a cast of mind which turns with natural eagerness to research, experiment and painstaking investigation. Such a mentality may be developed to extraordinary powers if bent and development run parallel, and yet can never proceed beyond the commonplace in the sphere of command.

Is it not then important to the service that there be kept alive an elastic system of human appraisal, which will be alert to detect latent possiblitities in every direction, among officers and soldiers, so that the army may create its own pre-eminent specialists and unfailingly put the right man on the right job?

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CALIBRATION

The editors of the JOURNAL frequently roam far afield in seeking for mental and spiritual fruits to pluck for the delectation of the readers of the JOURNAL. Sometimes these wanderings lead them into strange fields, as the reader may well believe if he has the patience to follow the sinuous windings of the thought of these next pages. The future holds the assignments of many new targets for our possible attack, and one of these is suggested in the apparently increased necessity for calibration, in connection with the development of long range firing.

It may well be that the future firing of Coast Artillery major caliber guns will fall under three rather distinct categories, from the standpoint of fire control:

(1) Firing at medium and short ranges.

(2) Firing at long ranges (beyond 15,000 yards) under conditions of good visibility.

(3) Firing at long ranges under conditions of poor visibility (such as fog, night, or through smoke screens).

For the future handling of problems under the first category, the fire control methods and experience in firing under the standard system developed in the Coast Artillery, are probably adequate.

Experiments are now being conducted to develop satisfactory methods of fire control to cope with the problem of long range firing. Barring some radical development or invention whose nature is not now foreseen, success in long range fire control almost seems to demand good visibility either from land stations, balloons, dirigibles, or airplanes.

However, conditions of good visibility are often lacking, and the Coast Artillery, if it is to fulfil its mission, must be able to fire with effect at night, or during any other condition of poor visibility. Success in this part of the field must come from:

First: The development of a special information service.

Second: The co-ordinate development of special methods of fire.

The problem of developing the special information service which would be needed is a whole subject in itself, demanding exhaustive investigation and experiment, and reference will be made to it in this discussion only to the extent of indicating the requirements from this service.

The special methods of fire necessary may be tactically characterized as interdiction fire on successive zones ahead of an advancing fleet or division.

Interdiction fire, to meet this sort of purpose, must provide a prohibitive volume of fire. In order to obtain the necessary volume:

(1) The zone must be restricted to the width of the channel actually practicable for capital ships, and the zone must be of no greater depth in a direction parallel to the channel than will be attained by the natural dispersion of the guns used. The covering of the zone will be obtained by distributing fire on a cross-channel line,—a sort of dead line, so to speak.

(2) The guns that can be brought to bear from any forts within range must be thrown into the concentration.

Such interdiction fire to be effective must have such a density that no ship could traverse the zone without encountering one or more rounds, and this density of fire must be provided by taking into consideration the number of guns available, their rate of fire, the speed of ships, length of vessels, width of channel, and dimensions of zones of dispersion.

To the editorial mind, it would seem that the employment of this kind of fire can promise success only by giving heed to something like the following tactical considerations:

(1) A timely warning from patrol boats, or other means of information in the specially developed information service already referred to, as to the time and direction of approach of hostile ships.

(2) The minimum duration of fire on one zone would surely be the time necessary for one division of battleships or battle cruisers to cross the zone. With average zones of dispersion and a 30-knot speed, this would be about 3 minutes.

(3) The fire should be shifted to successive zones in the direction of advance of the hostile ships. These successive zones must be separated by the distance a division would cover in the time necessary to execute the shift of fire, plus length of a division in exact column. This points to the necessity for careful drill and co-ordination of means of communication so as to reduce the time interval necessary in which to execute shifts of fire, and should result in a maximum interval of 3000 yards between successive zones.

Some of the technical considerations necessary to the employment of this kind of fire will be seen to be:

First: The perfection of the information service.

Second: A co-ordination of communication systems, and thorough drilling of personnel.

Third: The control of whole fire commands, or possibly fort commands, as units of fire.

Fourth: The calibration of all guns so that the necessary distribution of their centers of impact may be assured.

The idea of this kind of fire is really not new. It is a modification of the well known, but little exploited idea of using salvo points. However, instead of concentrating fire on a point we will distribute our fire on a line. Something of the same conception was doubtless in the mind of First Lieutenant, (now Brigadier General) John W. Ruckman, when he wrote an article on "Artillery Difficulties in the Next War," published in Volume II of the JOURNAL OF THE U. S. ARTILLERY, of October, 1893. The following quotation will be found on pages 555 and 556 of this volume:

> "A battery, we believe, should always concentrate its fire on a particular object. Groups of batteries in like manner should concentrate upon a prescribed vessel or vessels. Finally, such communication must exist between the central station and all batteries that the commanding officer can quickly and simultaneously direct all or any portion of his guns upon a given point or object. He would thus, so far as the application of tactics is possible, be able to use any kind of tactics suited to the defense, and concentrate all his guns upon any vessel he wished to overwhelm and destroy. In fact, with suitable devices and facilities, he could, we believe, so control and concentrate his fire as to draw a veritable 'dead line' upon the water."

It is believed that reflection will confirm the editorial notion evolved from pondering on these new problems, that calibration is going to assume a new significance of vast importance in long range firing, both under conditions of good visibility and control by observation, and in the execution of such special methods of fire as tactics will demand, under conditions of poor visibility.

For instance, a salvo of six guns observed will more accurately, and three times as quickly, give information as to the center of impact of a series of six shots than will three salvos from two guns. However, this possible advantage in the use of six guns cannot be obtained unless the six guns can be made to perform uniformly. Again, in firing without observation, using any scheme of interdiction fire, such as the one sketched, the effective distribution over the zone which is essential to success, can be guaranteed not alone by careful orientation and preparation of fire, but in addition by so absolute a calibration that the displacements of the centers of impact of all guns from their intended locations shall be uniform. In other words, with unobserved fire of this kind, the errors occurring will not leave gaps in the interdicted zone if the centers of impact are all in error by the same amount and in the same direction.

The consultation of the catalogue of the Library of the Coast Artillery School and the other indices there on file, shows the first specific reference to calibration, in any publication, to be an article by Colonel George F. E. Harrison, C. A. C., in the November-December, 1907, number of the JOURNAL OF THE U. S. ARTILLERY, on "Calibration of Seacoast Guns." Colonel Harrison begins as follows:

> "Calibration, as applied to guns, has not, as far as I can discover, ever been officially or authoritatively defined. It is well, for common and mutual understanding, that the meaning of the term be definitely set forth. I venture to define it as follows:
>
> "Calibration is the process by which, having determined the mean longitudinal error of each gun composing a tactical group or battery of guns, allowance or compensation is made for such mean errors in such manner as to reduce the mean error of the group or battery itself to a minimum."

In Hamilton's "Ballistics", Part I, Published in 1908, calibration is defined as follows:

> "Calibration, as the term is now used, is the process of ascertaining the peculiarities of individual guns of a battery and *correcting the range scale so that each gun ranges correctly* on an average."

A very similar definition is given in an article on "Practical Coast Artillery Gunnery," by "Gunner," in the January-February, 1908, number of the JOURNAL.

It is believed that Colonel Harrison's definition is preferable to Colonel Hamilton's, for the reason that it admits of allowing for the individual errors of guns in other ways than correcting the range scale. As no authorized definition of the term appears in the Coast Artillery Drill Regulations, the definition of Colonel Harrison will receive support in this editorial sanctum.

The procedure of calibration, as outlined in Colonel Harrison's article, in Hamilton's Ballistics, and in C. A. Memorandum No. 6, of 1908, provided for the firing of a very few rounds, from three to six, for each gun of the battery at a stationary target at mid-range, and carefully recording the lateral and longitudinal deviations. As a matter of fact, the procedure was not so simple, as those of us now grown old in the service will remember well. Everything about the battery adjustable and checkable was adjusted and checked before firing. The projectiles were groomed, not to say coached or even prayed over. The powder was blended, magazine temperatures were taken as tenderly as is the pulse of a fair maid by a young doctor. For every round to be fired, the seating of the projectile was measured, pressure plugs were inserted, and after the gun was loaded and laid, the elevation was verified by a clinometer set on a bore rest, inserted in the muzzle of the gun. Shades of Siacci! To this day the editorial heart goes pit-a-pat at the recollection of those heroes of yesteryear who, clustered nonchalantly around the mouth of the gun, with its stomach already tensed to disgorge the restrained irritation of 2250 ± f.s., dared the old gun to its worst, while they slandered it by their ballistic espionage on its range scale.

In the classical method of calibration every pitiless artifice was employed to wrest from the helpless gun its most secret error. Nevertheless, the application of the deductions from these firings so elaborately conducted, did not serve to make both guns of a battery shoot in perfect accord thereafter, in spite of the pains taken in the work of calibration.

The reasons for this apparently ungrateful response from our guns may be summarized briefly as follows:

(a) Most important of all, because the number of rounds fired was insufficient to determine the mean point of impact of the series which the few rounds fired only imperfectly represented.

(b) Because such a long time was allowed to elapse between rounds in order to accomplish all the meticulous checking deemed necessary, that meteorological conditions changed so that succeeding rounds actually were not even members of the same series.

(c) Because different gun carriages of a type formerly much admired did not equally expand corresponding parts under the influence of a common increase in temperature.

(d) Because two guns and carriages which will show a certain difference in performance at one range will not show the same difference in performance at other ranges.

(e) Because slipping the range scale of one gun to agree with the base piece at the range of calibration, throws out the gun so shifted from the possibility of either having its own proportionately corrected elevation for any other range, or of agreeing with the base piece at any other range.

(f) Because, even if two guns are made to agree at any time, subsequently when each has fired the same number of rounds, there will very probably exist a difference in wear which will cause them to vary their difference in range.

(g) Because, even if two guns develop a certain difference of range at a given range and while using a given ammunition, it is very probable that internal ballistic conditions will cause another difference of range when a different lot of powder or of projectile is used.

At the moment, there do not occur to the editorial mind any other reasons for the imperfection of the calibration method of former days. Perhaps yet others may be seen by the earnest reader, but for the moment these will suffice.

Indeed, the mere enumeration of all these shortcomings seems to brand the idea of a practicable solution of calibration as impossible.

At this point the editorial optimism comes to the fore with the assurance that practical results in calibration must be possible. This is immediately followed by the editorial suggestion which is the underlying reason for this editorial effort, that the problem of *calibration* is one of the many practical problems crying aloud to the thoughtful Coast Artillery officer for satisfactory solution.

There are already the footprints of various steps taken toward the solution of the problem, which may point the way for further advances.

It is now generally recognized that the results of any precision fire with good observation in land warfare may be used for calibration purposes. This serves to increase the data available from which to base, confirm, or correct the agreement between the guns. What is now needed is the means to utilize the data from shots fired at moving targets under favorable conditions for the same purpose.

The shifting of the range scale has gone by the board. "Heavy (Coast) Artillery Gunnery for Field Service," by Engelhardt and Thomson, the last word on the subject from the Coast Artillery standpoint, embodies American and French practice by saying:

> "It is not necessary in practice to fire a special series of shots to obtain the data for calibration, as almost any precision fire can be satisfactorily used for this purpose. In fact, with a battery having continuous observation for its firings, the calibration may be constantly kept up to date.
>
> "As the correction varies with the range and may increase with the amount that the guns have been fired, it is necessay to obtain data at least every 1000 rounds for the medium caliber artillery, and at least for the two ranges of 5000 and 10,000 meters.
>
> "From the precision firings select data which was taken on a clearly defined target or registration point near the middle of the field of fire and at a suitable range. This data should be that of an adjustment which includes improvement fire, or trial shots, for at least twelve rounds per piece.

> "For the same target, four adjusted elevations are obtained: A_1 (base piece), A_2, A_3, and A_4. The calibration corrections for the guns other than the base piece are then:
>
> $$C_2 = A_2 - A_1$$
> $$C_3 = A_3 - A_1$$
> $$C_4 = A_4 - A_1$$
>
> "These and similar results are used in preparing a table of corrections for each piece other than the base piece. The chief of section applies these corrections to the announced elevations. This practice permits the battery commander to compute the firing data for the base piece only, to adjust this piece on the target, and to open fire with the whole battery after the corrections for calibration and parrallax have been added."

However, the table of corrections thus suggested is based on one range only, and is good for only that range. For intance, referring to the only range table at the editorial elbow, at 11,000 yards the ΔR for 1 minute change in elevation is 14 yards, while at 19,500 yards the ΔR for 1 minute change in elevation is 7 yards. Suppose the battery calibrated at a range of 11,000 yards, and No. 2 gun falls short of No. 1 gun by 300 yards, necessitating an increase of 23 minutes. At 19,500 yards an increase of 23 minutes to the elevation for that range would only increase the range of the shot 161 yards.

However, another calibration firing at 19,500 yards would probably reveal the disparity between the guns to be neither 300 nor 161 yards, but something quite different.

Calibration firings have been held at various ranges, and a smooth curve of corrections obtained for use at all other ranges. Again, another method is cited on page 174 of "Heavy (Coast) Artillery Gunnery," above referred to:

> "Another method is to reduce the corrections, C_2, C_3, and C_4 to differences in muzzle velocity, since the erosion of the guns decreases the muzzle velocity. Subsequently, the firing data is computed separately for each gun assuming an erosion correction in terms of muzzle velocity."

The only trouble with throwing all the disparity between guns into muzzle velocity is that the individual errors of guns are affected by other matters than erosion, such for instance as variability of jump at different ranges, the errors from which causes, if they could be separated, would be found not to follow the curve of errors from differences in muzzle velocity.

The French conception, as taught by the American Field Artillery at the Saumur Artillery School, is embraced in the following quotation from page 120 of Volume 1 of the Manual of Artillery, published at Saumur in December, 1918:

> "Calibrating covers two general operations, first calibrating the instruments, and second, calibrating the guns."

The first operation, as explained in the text, consists in determining and recording the differences between instruments used in laying, after these instruments have been put in as perfect adjustment as possible, and using these differences as corrections to be applied with the corrections obtained from calibration firing at different ranges. Such a separation of instrumental errors from differences in ranging is indispensable.

Already this discussion has transcended the conventional editorial bounds of a few polite, pungent paragraphs, and while the various aspects of calibration have been but touched upon, the trail has been blazed to reveal calibration as the classical red thong which will bind the strength of each slender rod—the individual guns—into the smashing power of a tightly bound fasces.

♣ ♣ ♣

THE SWIVEL CHAIR

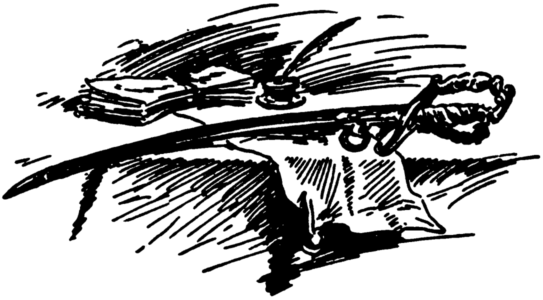
It is one of the results of human frailty that if any person, idea, or institution once acquires an odium of reproach, that odium will cling and persist like the effluvium of a pole-cat on a still and otherwise perfect night. Even so with the Swivel Chair. Justly or otherwise the Swivel Chair has been overwhelmed in the opprobrium which more discriminatingly would have aimed only at the Swivel Chair Artist and would have let the innocent Swivel Chair itself go unscathed.

For some time after induction to the editorial sanctum, the wielder of this pencil sat in a chair—just a plain chair, devoid of individuality and conventional as an old maid. There was not and is not anything the matter with the chair. As a chair, it is like some people—well finished and highly correct, but with a drab personality that leaves no impression on the eye of the beholder, (nor indeed in truth, upon the anatomy of the sitter).

Then one day there came into the life of the editor a new chair, yes, a Swivel Chair. The new chair is like a true friend, it accommodates its very attitude to one's slightest whim. If the editor bends to his task, the faithful chair rears its back square and straight and holds him to his task; if the editor would lean far back to drag a reluctant idea from the spot of missing kalsomine in the ceiling, the chair, like a wise woman, yields to the suggestion and bends to his will. If the editor's mood swings him to the right to reach his faithful pipe, or to the left to punish a long-suffering typewriter, the complaisant chair follows his mood.

By reason of his association with this Swivel Chair, if not for other reasons, the author of these trenchant lines is doubtless tarred with the brush that brands him a Swivel Chair Artist. So he may not jump to the defense of Swivel Chair Artists as a tribe, for his evidence would be discredited as that of a non-disinterested witness, "if you know what I mean."

However, with at least the valor of a certain ancient Spanish knight, he will arise to the defense of his friend, the Swivel Chair itself, and to the whole tribe of Swivel Chairs. Swivel Chairs are the Good Samaritans among chairs. For all those, and particularly for those who are ill-upholstered, who must go down to their work in chairs, the Swivel Chair is a patient and ever-faithful friend.



PROFESSIONAL NOTES

Civil War Ordnance and Gunnery

By Brig. General Henry L. Abbot, Retired

Now that the Great War has probably come to an end, the press teems with details respecting the new methods and implements employed. To appreciate the wonderful advance in these details, one should have a definite starting point for comparison. In the operations of the First Connecticut Artillery, which served all the heavy guns in front of Richmond in the campaigns of 1864-65, great attention was given to noting all important details; and in my final report to the Adjutant General of Connecticut, on the muster-out of the Regiment, I incorporated many of them. This Report is not easily accessible to readers of the Artillery Journal, and I therefore quote the following from pages 62-70 of the Annual State Report for the year ending March 31, 1865. The fact that modern trench warfare largely originated in our Civil War is too well known to require mention. As to air-planes none existed at that date, but considerable use was made of balloons held captive by ropes; they gave good views of the enemy's lines. An incident occurred on the Petersburg front worthy of note. General Fitz John Porter when about to make an ascension fortunately noted that the wind was blowing toward our lines. When he reached the desired height, some two or three thousand feet, the rope broke and he found himself rapidly blown toward the enemy and prison. He at once operated the valves to descend; and reaching the favorable current after a tour over their trenches he landed safely within our lines. It was the first air reconnaissance on record:

"Considering the large amount of firing, the injuries suffered by our guns have been unusually small—being limited to blowing off the muzzle of a 30-pdr. Parrott about a foot from the face—probably by a premature explosion of the shell; it was cut smooth with a cold chisel, and the accuracy of the piece seems not at all impaired; and to the bursting of the 5.8-inch Sawyer gun, which occurred on August 5, after firing ten rounds. The gun had already been fired a large number of times at Fort Monroe. It burst into four principal parts—the largest including the trunnions and all in front of them remained in its place on the carriage—the next piece, forming the bottom of the bore near the breech, fell between the cheeks—the left half of the top—which split as usual through the vent, fell upon the top of a return of the parapet a short distance from the gun—the right half was thrown some 200 yards entirely outside the fort. The vent was evidently defective, showing a double cavity, much enlarged. The strength of the gun being doubtful, it was fired by quick-match, consequently no one was injured.

"The only novelty in the service of the Siege Artillery requiring special notice has been the method of mounting the 13-inch mortar, the extreme weight of which (17,000 lbs) renders it unmanageable. Maj. Gen. Butler conceived the idea of serving it upon a railroad car, and ordered one made as an experiment. The first car broke under the shock. A second, prepared by the Engineers in charge of the Military Railroad, answered its purpose admirably. It consisted of an ordinary truck car, strengthened by additional beams tied strongly by iron rods and covered by iron plating. Fired with 14 lbs. of powder, the mortar recoiled upon the car less than two feet, and upon the track some ten or twelve feet. It was a decided success. On one occasion three different observers reported that a shell burst under a gun and blew it and its carriage entirely above the parapet. Certain it is that the mortar was much dreaded by the enemy.

"(Page 51) The 13-inch mortar, which was served on a railroad truck car made so strongly as to resist the shock of firing, was drawn to City Point by a locomotive.

"(Page 63 continued) During the campaign, it has been necessary to conduct certain experiments, to facilitate the fire of the batteries. Among them was the deducing of a table of ranges for the 8-inch Siege Mortar which differs materially from the old model in this respect, owing to the substitution of the elliptical for the Gomer chamber. The ranges were determined with care." (Here follows a table of ranges covering 2225 yards, made in September 1864.)

"Another experiment was to test a new shell invented by Mr. Pevey. It consists of two concentric shells thinner than usual, and connected firmly by studs. The open space between is filled with small iron balls or incendiary composition. Shells for trial both 10-inch and 8-inch were ordered by General Butler, and the result indicated by bursting them over water and over a dusty plain was highly satisfactory. In my judgment they will break into more than double the number of fragments of the ordinary shell, and consequently have fully double the effect. They bore the shock without injury although one 10-inch shell was thrown from a Sea Coast Mortar with a charge of about seven lbs. of powder.

"Another experiment was to test the light balls furnished for our 8-inch mortars. It was found that on ground of ordinary hardness, no larger charge than six oz. of powder giving a range of only 255 yards, could be used without causing the ball to break into fragments from the force of its fall. This range is entirely too short for our purposes. Possibly by using an elevation less than 45°, the range might be lengthened, but in my opinion the balls are not made of sufficient strength to be practically useful.

"Other important experiments with new projectiles incendiary, double and triple bursting, etc., have been made, but the results are withheld for the present.

"The subject of Mantlets to protect the gunners has received considerable attention. Those furnished by the engineer department are made of rope, five feet by four and one half feet, and about six inches thick, weighing about 600 lbs. each. They are excellent for protection, but their great weight makes them difficult to handle. In my judgment it might be safely reduced by lessening their thickness. The penetration in them of an elongated bullet from a Springfield rifled musket at 20 paces is less than 3 inches. I had also an opportunity to see the effect of a 10-pdr. rifled projectile at 600 yards range upon a rope mantlet made at Fort Monroe, and only about 4 inches thick. The shot was deflected, breaking the lashing of the mantlet, and throwing down the pole supports, but was so much checked in velocity by so doing as then to knock a man down without seriously injuring him. In other cases these thin mantlets have been penetrated even by musket balls where the ropes were not closely lashed together, but the experience of the campaign has convinced me that a thickness of 4.5 inches is, all things considered, the best which can be given them.

"In this connection it may be well to call attention to the fact that we have had great difficulty in drawing heavy guns and supplies through the covered ways leading to Fort Sedgwick, owing to the sharp curves at the angles. In such places security must in part be sacrificed to facility of of travel, or great delays may result in moving siege guns. Our guns have been more than once dismounted in turning these corners.

"As most of the magazines have been made under the superintendence of my officers, it may be well to state that the plan adopted, putting them in secure positions and making the chamber entirely below ground, roofed by heavy logs and covered by dirt about six feet thick, has been found to be both simple and safe. Boards have seldom been used either for the sides or for the floor, which is made to drain into a barrel sunk near the entrance. The usual dimensions, in the clear, have been six feet wide by five feet deep, length to vary according to capacity required. In no instance has one of them been blown up, although often hit by the Confederate projectiles, and even in heavy rains, such as that of August 15, at Petersburg when several soldiers in the low bottom were washed away and drowned, very little loss of ammunition has occurred from leakage.

"The large amount of mortar firing during this campaign has disclosed one defect which should be corrected. The friction primers are driven out of the vent with great violence by the explosion, and occasion serious danger to the cannoniers. One valuable officer of my regiment, Lieut. Andrews, lost the sight of one of his eyes from this cause. Another, Lieut. Jackson, had a narrow escape, being severely cut on the forehead, while the instances of injury more or less serious to enlisted men, will, I think fully amount to a dozen. The vents should be covered by a cap similar to that used for the Whitworth gun, and the line of metal should be permanently and accurately marked on all Mortars. Moreover what is not the case now, some convenient hook should be arranged for guiding the lanyard into a direction perpendicular to the vent. In other respects I regard the new mortars and carriages as vast improvements over the old models, in fact, as perfect.

"The siege guns and carriages now in use are generally excellent. Much trouble, however, has arisen from the breaking of the new elevating screws of the 30-pdr. Parrotts, which are ill adapted to their purpose. A more general defect, which applies to rifled guns of all calibers, is that little or no care is used in their sights. For a sharpshooter who is expected to fire more than five or six hundred yards with his rifle, we supply accurate globe sights and a fine telescope. For a rifle gun which is to fire 3000 yards, we give sights far courser than those of any old smooth-bore musket. Rifled artillery can never accomplish all that it ought, until accurate telescopic globe sights are furnished.

"Several precautions to insure rapidity and precision of mortar fire, have been suggested by the intelligent observation of Capt. Osborne, Lieut.

Jackson, and other officers commanding batteries. Thus a wooden-handled steel scraper, made in the shape of a hoe with a double edge,—curvature 6.5 inches,—was found to reduce more than one-half the time required to serve the 13-inch mortar. Although the fuses for this mortar were old and poor, they were made to almost invariably burn by driving them gently so as not to shake out the composition, and by placing a train of dry powder from the top of the shell to the fuse, and another, where the fuse would strike the bottom of the bore in rolling out,—both made to remain in place by wetting the iron. It was also found that wooden fuses should not be sunned; that the powder should be well stirred in the barrel before firing, and that, in inserting the Coehorn shell, its paper fuse should be placed near to the top of the bore to insure its ignition.

"We may derive some useful hints from the Confederate smooth-bore ammunition. Thus: their Coehorn shells are provided with ears, which is a great improvement over our system of banding. The interior surfaces of some of their 12-pdr. shells are regular dodecahedrons; of others, they consist of an upper and lower pentagon, connected by ten equal trapezoids. The effect of both these devices is to cause the shell on bursting to divide into twelve pieces weighing about a pound each, and thus to secure the maximum effect. It is a decided success, —the former shape appearing to be more uniformly successful than the latter. Their system of filling spherical case with iron balls is a failure, the weight not being sufficient to render them effective.

"The great problem,—what is practically the best projectile for rifled artillery,—has been carefully investigated during this campaign, both by requiring full reports of our own firing, and by carefully collecting all varieties of projectiles fired by the Confederates in return. Drawings of this collection, and of our own projectiles have been made, and the collection itself has been sent to the Military Museum at West Point.

"The following facts as to the Confederate rifled projectiles are worthy of notice. Their variety is very great, about seventy different kinds having been collected. They may however be classified into nine systems, according to the devices for making them take the grooves.

"The first device is a cupped copper plate, secured to the shell by a screw, and held firm by radial grooves, generally seven in number, but sometimes six. One sample bears Brooke's name upon the cup. It seems to be confined to the heavier guns exclusively,—samples of the calibers 7 inches, 6.4 inches, and 4.2 inches, alone being collected. The projectiles appear to take the grooves well, but their plates are often missing,—showing that it would be dangerous to use them over our troops.

"The second device consists of making the projectiles of wrought iron, the bottom cupped like a lead bullet. This is rare, only three calibers, 7 inches, 6.4 inches, and 4.62 inches, being collected. It seems to be faulty only from its expense. The samples were solid shot, apparently designed for firing at iron-clad vessels.

"The third device is a curved copper plate, secured by a screw, and held firm by three dowels, made sometimes of three copper projections from the plate, extending into holes in the iron base of the shell, and sometimes of three iron projections from the base of the shell, extending through holes in the plate. The explosion of the powder flattens the plate, and thus gives the rifled motion by increasing its caliber. This system is liable to the objection that the plate almost invariably separates from the shell, rendering the projectile unfit to be used over troops. It is however quite common, samples of the following calibers having been collected: 7 inches, 6.4 inches, 4.62 inches and 2.2 inches. It is even used to render serviceable, projectiles made upon other systems which are failures.

"The fourth system is that of Reed, which closely resembles Parrott's. This is very common, no less than twenty different kinds of projectiles being collected. Seven have wrought iron cups, calibers 6.4 inches, 4.2 inches, 3.67 inches, and 3 inches. Eleven have copper rings, calibers 8 inches, 7 inches, 4.62 inches, 4.2 inches, 3.67 inches, and 3 inches. The larger samples are rare, but for field guns this seems to be the standard system. The different devices for attaching the ring are numerous, and are worthy of study,—one, especially, in which the shell apparently never fails to take the grooves and never loses the ring, nor throws off fragments of iron from its base,—faults to which most of the other devices seem liable.

"The fifth system takes the grooves by the expansion of a lead sabot. It seems to be chiefly confined to large calibers, The lead sometimes remains upon the shell, but is very liable to strip.

"The sixth system is that of Mr. Whitworth, whose 12-pdr. guns the Confederates use considerably. Some of the projectiles are English, and some of Confederate manufacture. They have even tried to make shells by boring out a cavity in the bolt to the diameter of their usual fuse-hole (0.9 inches). This, however, does not contain a sufficiently large bursting charge to be of service.

"The seventh system,—which is in common use,—is that of Mr. Hotchkiss. Many of these projectiles are evidently of our manufature, bearing Mr. Hotchkiss' name and patent stamp. Others have no mark, and are without doubt of Confederate manufacture. I have such samples for calibers 5.2 inches, and 3.3 inches, as well as 3 inches. The one of 3.3 inches has a large wire wound around the middle and covered by the lead, which I have never seen in those supplied by Mr. Hotchkiss.

"The eighth system is in some doubt. The specimen is one of Mr. Schenkl's old model 30-pdr. projectiles, which may possibly have been received from our batteries and fired back. It, however, has the characteristic copper fuse-plug of the Confederates, and they evidently must have made a sabot for it,—of what material is not known.

"The ninth system is that of the English Armstrong and Blakely flanged projectiles,—samples of which were captured at Fort Fisher—but none of which have been used on these lines.

"Among the ammunition captured by the 18th Corps near Fort Harrison, were several samples of 100-pdr. and 30-pdr. projectiles, which I have issued for use to my batteries.

"There has been so much discussion of late as to the merits of the different kinds of guns and ammunition now in use in our service, that I have decided to report upon certain of our records—remarking that it is possible that future firing may modify the results obtained."

Here follow three tables based upon the daily reports of the batteries, where men were specially detailed under the close supervision of the battery commanders to note the effect of every shot. If any uncertainty exists, the shot is entered as uncertain, and is not included in the final ratios. These tables show for guns, the number of times fired and resulting condition; for ammunition, the numbers which took the grooves or tumbled, and the percentage; for fuses, the percentage serviceable. Such records have not often been kept in actual service, but are valuable for problems of the day. After the lapse of half a century they need not be quoted.

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Artillery on Firing Line November 11

On November 11, 1918, there were 92-2/3 regiments of artillery, fully equipped, either at the front or resting after action. There were also at the front anti-aircraft units and a naval detachment. The pieces manned by these troops were as follows:

Field Artillery.

	Regiments.	Pieces.
75-mm. guns	50	1200
4.7-in. guns	2	48
155-mm. howitzers	25	600
155-mm. guns	3	72
Total	80	1920

Coast Artillery.

155-mm. guns	4	96
8-in. howitzers	3-2/3	88
9.2-in. howitzers	1	24
240-mm. St. Chamond	1/3	6
Railway artillery	3-2/3	66
Anti-aircraft guns	..	46
Total	12-2/3*	326

Navy.

14-in. guns	..	5
Grand total	92-2/3*	2251

*In addition to anti-aircraft and naval units.

◆ ◆ ◆

True North by Altitude of Any Star

By Captain W. D. Hohenthal, C. A.

This method of determining True North by the Altitude of any Star, while simple, accurate, and available under more conditions than any other method is not in general use. The reason perhaps being that the average engineer or artillery officer is adverse to use the stars because he knows so few of them and is inclined to believe that such knowledge of the stars belongs only to the astronomer and navigator. As a matter of fact, with the aid of a good star chart identification of constellations and individual stars is nothing more than a simple map reading problem which should be within the ability of all officers and non-commissioned officers of the army.

The training of officers at Fort Monroe during the emergency demonstrated that the "Time" element in astronomical observations caused more trouble than anything else. The method presented here eliminates the "Time" element, it being necessary to know only the approximate date.

The two standard methods of determining Azimuth—Polaris and Alitude of the Sun, limit the observers field to one portion of the heavens; the method by altitude of any Star will allow him, in bad weather, to take advantage of a break in the clouds.

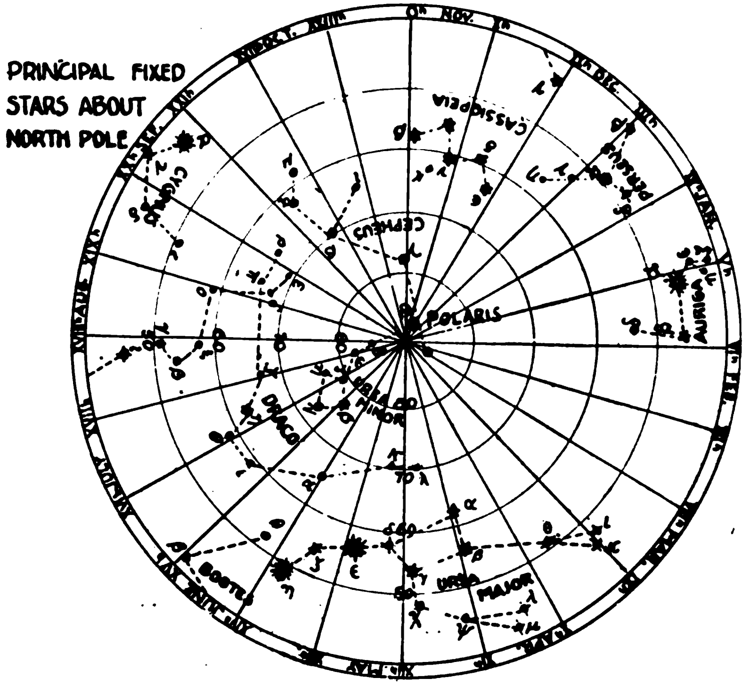
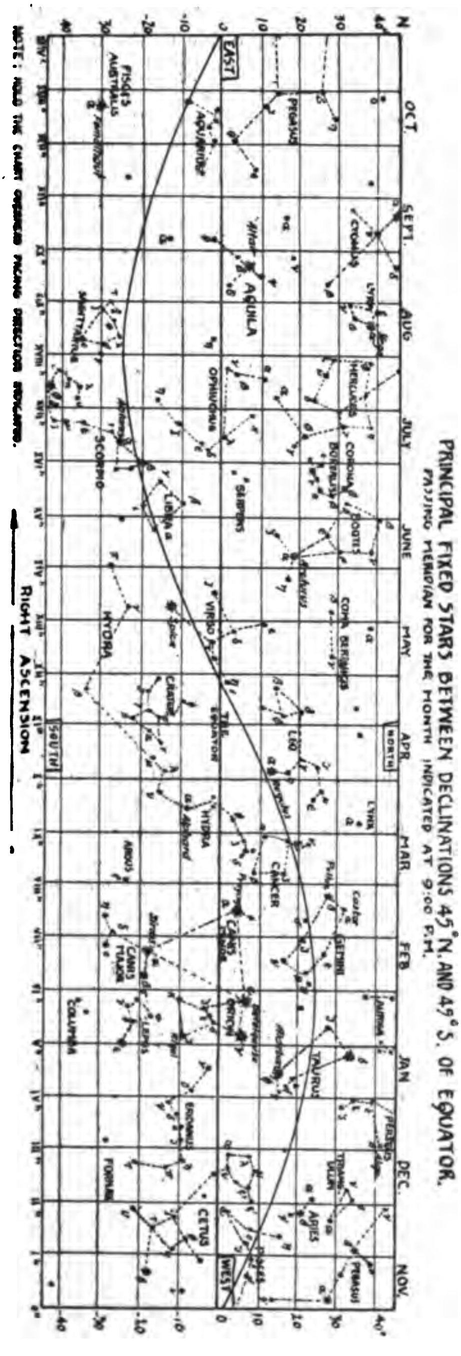


Fig. 1

2414

Briefly, the principle of this method is the solution of the Celestial triangle whose vertices are the Pole, Zenith, and the star, and whose sides will be co-altitude, co-latitude, and co-declination. Knowing three quantities of a spherical triangle we can easily determine any other. We find the star's declination from an Ephemeris or table, our Latitude from a reliable map or previous Latitude observation, and the altitude of the star by means of a transit instrument. By means of a suitable formula, we compute the horizontal angle between True North and the star at the instant of observation and having measured the horizontal angle between the star and some reference mark at that instant, the true azimuth is a matter of addition or sub-

2416

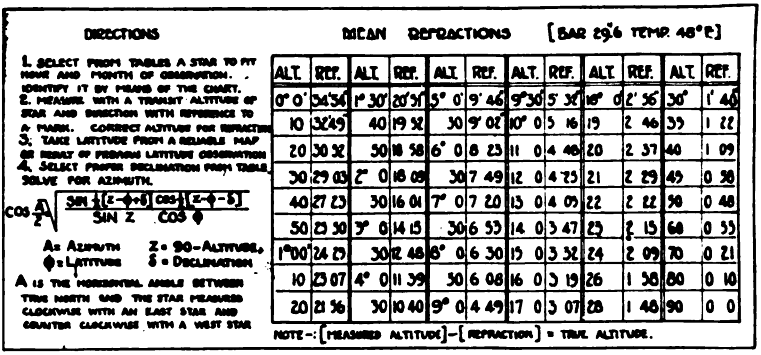

PRINCIPAL FIXED STARS BETWEEN DECLINATIONS 45°N. AND 45°S. OF EQUATOR.
PASSING MERIDIAN FOR THE MONTH INDICATED AT 9:00 P.M.

NOTE: HOLD THE CHART OVERHEAD FACING DIRECTION INDICATED.

Fig. 3

traction. The method and Formula for solution is exactly the same as the standard Solar although it is more simple due to the fact that as the sun's declination changes very rapidly, in order to know the true declination, Greenwich time must be known. A star's declination changes very slowly and may be considered a constant during the month.

The accompanying charts were designed for use in the Coast Artillery school at Fort Monroe and used in the advanced Orientation Course with success. If pasted in the back of a table of logarithms they will always be available for use as they are complete in themselves. Fifteen of the brightest stars have been tabulated in such a manner that the observer will generally be able to find half a dozen during the early evening that are easily identified and will make strong triangles. This list can of course be extended by reference to the American Nautical Almanac (Superintendent of Documents, Washington, D. C. price 15 cents).



DIRECTIONS

1. SELECT FROM TABLES A STAR TO FIT HOUR AND MONTH OF OBSERVATION. IDENTIFY IT BY MEANS OF THE CHART.
2. MEASURE WITH A TRANSIT ALTITUDE OF STAR AND DIRECTION WITH REFERENCE TO A MARK. CORRECT ALTITUDE FOR REFRACTION.
3. TAKE LATITUDE FROM A RELIABLE MAP OR RESULT OF PREVIOUS LATITUDE OBSERVATION.
4. SELECT PROPER DECLINATION FROM TABLE. SOLVE FOR AZIMUTH.

$$\cos\frac{A}{2} = \sqrt{\frac{\sin\frac{1}{2}[z-\phi+\delta]\,\cos\frac{1}{2}[z-\phi-\delta]}{\sin z\ \cos\phi}}$$

A = AZIMUTH Z = 90 − ALTITUDE,
φ = LATITUDE δ = DECLINATION

A IS THE HORIZONTAL ANGLE BETWEEN TRUE NORTH AND THE STAR MEASURED CLOCKWISE WITH AN EAST STAR AND COUNTER CLOCKWISE WITH A WEST STAR

MEAN REFRACTIONS [BAR 29.6 TEMP. 48°F]

ALT.	REF.	ALT.	REF.	ALT.	REF.	ALT.	REF.	ALT.	REF.	ALT.	REF.
0° 0'	34' 34"	1° 30'	20' 31"	5° 0'	9' 46"	9° 30'	5' 32"	18° 0	2' 56"	30°	1' 40"
10	32' 49"	40	19 52	30	9' 02"	10° 0	5 16	19	2 46	35	1 22
20	30 32	50	18 58	6° 0	8 23	11 0	4 48	20	2 37	40	1 09
30	29 03	2° 0	18 09	30	7 49	12 0	4 25	21	2 29	45	0 58
40	27 23	30	16 01	7° 0	7 20	13 0	4 09	22	2 22	50	0 48
50	25 50	3° 0	14 15	30	6 53	14 0	3 47	23	2 15	60	0 33
1° 00'	24 25	30	12 48	8° 0	6 30	15 0	3 32	24	2 09	70	0 21
10	23 07	4° 0	11 39	30	6 08	16 0	3 19	26	1 58	80	0 10
20	21 56	30	10 40	9° 0	4 49	17 0	3 07	28	1 48	90	0 0

NOTE—: [MEASURED ALTITUDE]−[REFRACTION] = TRUE ALTITUDE.

Fig. 2

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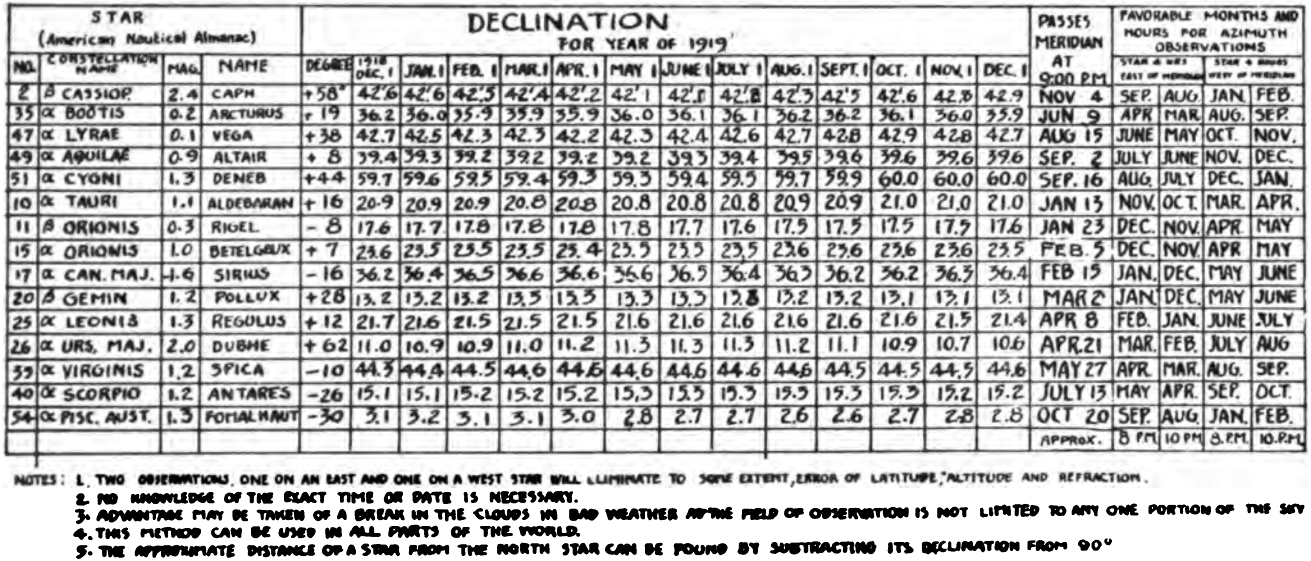
The charts were intended primarily for the man who had no training in Astronomy but who had knowledge of logarithms and the ability to use a transit. During the past six months it has been demonstrated as very practicable and handy in the field and has been used by several trained observers in preference to other methods.



STAR (American Nautical Almanac)				DECLINATION FOR YEAR OF 1919														PASSES MERIDIAN AT 9:00 P.M.	FAVORABLE MONTHS AND HOURS FOR AZIMUTH OBSERVATIONS			
NO.	CONSTELLATION NAME	MAG.	NAME	DEGREE	1918 DEC. 1	JAN. 1	FEB. 1	MAR. 1	APR. 1	MAY 1	JUNE 1	JULY 1	AUG. 1	SEPT. 1	OCT. 1	NOV. 1	DEC. 1		STAR 4 HRS EAST OF MERIDIAN		STAR 4 HOURS WEST OF MERIDIAN	
2	β CASSIOP.	2.4	CAPH	+58°	42'6	42'6	42'5	42'4	42'2	42'1	42'5	42'8	42'3	42'5	42'.6	42.8	42.9	NOV 4	SEP.	AUG.	JAN.	FEB.
35	α BOÖTIS	0.2	ARCTURUS	+ 19	36.2	36.0	35.9	35.9	35.9	36.0	36.1	36.1	36.2	36.2	36.1	36.0	35.9	JUN 9	APR	MAR.	AUG.	SEP.
47	α LYRAE	0.1	VEGA	+38	42.7	42.5	42.3	42.3	42.2	42.3	42.4	42.6	42.7	42.8	42.9	42.8	42.7	AUG 15	JUNE	MAY	OCT.	NOV.
49	α AQUILAE	0.9	ALTAIR	+ 8	39.4	39.3	39.2	39.2	39.2	39.2	39.3	39.4	39.5	39.6	39.6	39.6	39.6	SEP. 2	JULY	JUNE	NOV.	DEC.
51	α CYGNI	1.3	DENEB	+44	59.7	59.6	59.5	59.4	59.3	59.3	59.4	59.5	59.7	59.9	60.0	60.0	60.0	SEP. 16	AUG.	JULY	DEC.	JAN.
10	α TAURI	1.1	ALDEBARAN	+ 16	20.9	20.9	20.9	20.8	20.8	20.8	20.8	20.8	20.9	20.9	21.0	21.0	21.0	JAN 13	NOV.	OCT.	MAR.	APR.
11	β ORIONIS	0.3	RIGEL	- 8	17.6	17.7	17.8	17.8	17.8	17.8	17.7	17.6	17.5	17.5	17.5	17.5	17.6	JAN 23	DEC.	NOV.	APR.	MAY
15	α ORIONIS	1.0	BETELGEUX	+ 7	23.6	23.5	23.5	23.5	23.4	23.5	23.5	23.5	23.6	23.6	23.6	23.6	23.5	FEB. 5	DEC.	NOV.	APR	MAY
17	α CAN. MAJ.	-1.6	SIRIUS	- 16	36.2	36.4	36.5	36.6	36.6	36.6	36.5	36.4	36.3	36.2	36.2	36.3	36.4	FEB 15	JAN.	DEC.	MAY	JUNE
20	β GEMIN	1.2	POLLUX	+28	13.2	13.2	13.2	13.5	13.3	13.3	13.3	13.8	13.2	13.2	13.1	13.1	13.1	MAR 2	JAN.	DEC.	MAY	JUNE
25	α LEONIS	1.3	REGULUS	+ 12	21.7	21.6	21.5	21.5	21.5	21.6	21.6	21.6	21.6	21.6	21.6	21.5	21.4	APR 8	FEB.	JAN.	JUNE	JULY
26	α URS. MAJ.	2.0	DUBHE	+ 62	11.0	10.9	10.9	11.0	11.2	11.3	11.3	11.3	11.2	11.1	10.9	10.7	10.6	APR. 21	MAR.	FEB.	JULY	AUG
39	α VIRGINIS	1.2	SPICA	-10	44.3	44.4	44.5	44.6	44.6	44.6	44.6	44.6	44.6	44.5	44.5	44.5	44.6	MAY 27	APR.	MAR.	AUG.	SEP.
40	α SCORPIO	1.2	ANTARES	-26	15.1	15.1	15.2	15.2	15.2	15.3	15.5	15.3	15.3	15.3	15.3	15.2	15.2	JULY 13	MAY	APR.	SEP.	OCT.
54	α PISC. AUST.	1.3	FOMALHAUT	-30	3.1	3.2	3.1	3.1	3.0	2.8	2.7	2.7	2.6	2.6	2.7	2.8	2.8	OCT 20	SEP.	AUG.	JAN.	FEB.
																		APPROX.	8 P.M.	10 P.M.	8 P.M.	10 P.M.

NOTES: 1. TWO OBSERVATIONS, ONE ON AN EAST AND ONE ON A WEST STAR WILL ELIMINATE TO SOME EXTENT, ERROR OF LATITUDE, ALTITUDE AND REFRACTION.
2. NO KNOWLEDGE OF THE EXACT TIME OR DATE IS NECESSARY.
3. ADVANTAGE MAY BE TAKEN OF A BREAK IN THE CLOUDS IN BAD WEATHER AS THE FIELD OF OBSERVATION IS NOT LIMITED TO ANY ONE PORTION OF THE SKY
4. THIS METHOD CAN BE USED IN ALL PARTS OF THE WORLD.
5. THE APPROXIMATE DISTANCE OF A STAR FROM THE NORTH STAR CAN BE FOUND BY SUBTRACTING ITS DECLINATION FROM 90°

Fig. 4

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The Airplane in Surveying and Mapping

By Colonel E. Lester Jones.
Superintendent, U. S. Coast and Geodetic Survey

Reprinted from "Flying," June, 1919

The aeroplane, while not a product of the war, owes its present very prominent place to the war, and if it had not been for the war its development would have been retarded many years. It had few practical uses from the time the Wright Brothers first flew their machine at Fort Myer, Virginia, in 1909 until 1914. They were playthings to amuse the holiday crowd.

The war changed this situation. The allies and the central powers almost immediately saw the great importance of the airplane in battle and the best brains and energy of the warring nations were given to the problem of making the airplane perform what a few years ago would have been considered miraculous things.

War planes were made for various purposes, which I need not enumerate. But the most important thing done from the airplane was photographing the enemies' lines and thereby discovering the positions of the batteries, ammunition dumps, the truck systems, and other military facts and features.

The same methods, with some modifications, are now being considered in connection with the mapping of extensive areas by the map-making organizations of the country. In fact, some work has already been done and experiments are being carried on which promise excellent results.

There is so much misinformation regarding surveys and maps, that it seems appropriate for me as the head of the oldest map-making bureau of the government, to present the mapping situation to this Congress, both for your information and as a matter of record.

Surveying and mapping have long histories and the development of the methods now employed took centuries. But the method of airplane surveying has developed like a mushroom. To what extent is it applicable to our needs? This I shall endeavor to show.

In collecting data for a map those surveying methods must be adopted in any particular case that suit the requirements. If one should wish only a route map running from one village to another, it would be perfectly satisfactory to use a compass for direction and the pacing of a horse or the readings of an odometer on a wheel for the distance between the two points. But maps are usually not so simple as that.

TYPES OF MAPS

There are several types of high grade maps needed in the country. One must be made along the coasts to show the location of the actual shore line and the character of the ground immediately back of the coast in order that the navigator may be able to locate himself from topographic features along the shore, should he be driven off his course during a storm. In addition the depths of the water and all obstructions to navigation must be indicated on this map or chart, the elevation and shape of the ground on islands and just back of the coast must be shown on the map by contours.

A second class consists of maps on which the features other than elevations and contours are shown in their correct horizontal positions. This type of map would be practically the same as the third type where the area covered is very level. Such an area would be the coastal plain of Louisiana.

The third class covers maps of the interior or of large islands on which all features, cultural and natural, are located in their proper horizontal position and contours are shown to give the elevations of the ground and the shape of the hills, ridges, valleys, etc. This map would be used by engineers in laying out railroads and highways, and in conducting various classes of engineering work.

These three classes of maps are the ones in which we are most directly interested.

The map which shows the horizontal positions of cultural and natural features on the surface of the earth but no contours can be made more rapidly than the one which requires contouring. All that is needed in the former case is some method of obtaining the direction and distance between each two features in the area to be surveyed. The usual method of making such a map is by compass and chain or by transit and tape or transit and stadia or by the plane table. These methods are all very closely allied and such accuracy as may be demanded may be obtained by varying the methods used.

Maps Controlled by Fixed Points

In any event there must be within the area to be surveyed, if it is a large one, a number of control stations. These control stations consist of triangulation stations placed on the highest parts of the ground or traverse stations which may be along the roads, which are accurately located in latitude and longitude and which are accurately and substantially marked with concrete or rock in order that they may be recovered and identified by any surveyors or engineers who wish to use them.

There are now many thousands of such stations in the United States, established principally by the Coast and Geodetic Survey, available for the fundamental control of surveys and maps. From the stations established by that Bureau control of the same or of a lower grade of accuracy may be extended in any direction for the immediate control of topographic maps.

Overlaps, Gaps and Offsets to be Avoided

It is readily seen that without the fundamental control, which extends over the whole area of the United States, there would be great confusion. If the control in any one state is not properly coordinated and correlated with that of any other state near it, the result will be that when different topographic surveys and maps are joined there will be overlaps, gaps, and offsets which cause no end of trouble and confusion to the cartographer and map maker. When there is a single system of control for the whole country we avoid this unfortunate condition.

3,000,000 Square Miles, Less Than One Half Mapped

There is today only about 40 per cent of the 3,000,000 square miles of the United States mapped both as to horizontal positions of the features and the elevations by contours of hills, ridges, valleys, etc. These are the maps of class three, mentioned previously. Some of the 40 per cent of the surveyed area will have to be resurveyed because the original work was done many years ago when methods were not as refined as they are today and the demands of map users were not as exacting as they are at present. It is safe to say that not over 30 or 35 per cent, or one-third of the whole country is adequately mapped.

The question is, what shall be done with the other 60 per cent. This is a question that is puzzling map makers constantly and no ready solution is at hand provided we insist on having a map of the whole area within a few years.

It is possible that here may be a valauble field for the aeroplane. It is not believed that the aeroplane unsupported by other surveying can give the final accuracy required in original surveys. But by its means can be made a map that will be much better than the maps which may be in existence today in the areas which have not been topographically mapped. In order that the remaining 60 per cent of the country might be mapped by aeroplane it would be necessary to have a great amount of triangulation and traverse run with a view to furnishing the horizontal control for the photographs to be made by the aeroplane. With this control, it would be possible to fit the photographs on the map into their proper positons.

AIRPLANE SURVEYING WILL DEVELOP

It is not possible to run many miles with aeroplane photographs and expect to have a very high degree of accuracy in the resulting maps and here I wish to give a word of caution to the advocates of aeroplane mapping, that everything cannot be expected of aeroplane mapping. The development of this science will undoubtedly be rather slow for a few years. After it has been developed methods must, of course be thoroughly tested before they can be adopted. It is well that this is so for otherwise haste might cause mistakes which would discredit the method to such an extent that it would take years to recover.

CHARTS OF THE COASTS

The first class of maps considered here consists of charts of the Coast and Geodetic Survey which show the level area immediately along the coast and the water area for some distance out from the shore. The purpose of coast charting is to furnish a safe means of communication by vessels along the coast or in approaching the coast. At present, the methods employed are the usual ones for the topographic surveying of the shore line and the area immediately back of it and the ordinary hydrographic methods of surveying in the water.

The coast line of the United States has been mapped but the currents and waves of the oceans cause many large changes in the shore line. In the case of Fire Island entrance, Long Island, New York, this was changed in position about four miles in fifty years. The changes are so rapid that frequent resurveys of the coast must be made to furnish exact and reliable information to the navigator. It is also necessary to revise the area just back from the coast, for roads are frequently changed in position or abandoned, new ones are established, houses are built or burned, villages spring up, woods are removed or grow over what were vacant fields at the time the map was made and all of these changes should be shown for the use of the mariner. The question arises as to how such revision shall be made.

REVISION OF CHARTS BY AIRPLANES

From the experience of the engineers of the Coast and Geodetic Survey the revision of an area that does not need contouring is almost as expensive and takes almost as much time as the original survey, for it is necessary to make a test of the position of each feature. It is here that the aeroplane will be of the greatest service, for if a portion of the shore line should be inspected with a view to learning whether or not the map of it should be revised, we could have a series of photographs made by an aeroplane along the coast, and a comparison of the photographs with the original map would enable one to locate very definitely each area within which there are new features or where old ones have changed. It is believed that in most cases the details on an airplane photograph could be placed on the map from the photograph with all of the accuracy that is needed in the topography shown on the coast charts.

It is a debatable question as to whether the aeroplane photograph made over a water area will show any outline of dangers to navigation when the plates are developed. If they are shown, there is a vast field for the aeroplane in making photographs over water areas where it is known that many obstructions exist. With the usual surveying methods, it is difficult at times to locate every obstruction. One or more on any chart might be missed. The fact has been proved a number of times in a most disastrous way by vessels running on uncharted rocks both along our eastern and our western coasts and especially in Alaska.

The Coast and Geodetic Survey is now making wire drag surveys of all doubtful areas along the coast but it will be many years before the bureau can assure the navigating public that all obstructions have been found and accurately charted.

Airplanes and Hydrographic Surveys

It may be possible that an aeroplane photograph will indicate submerged rocks or other dangers that are close to the surface of the water. It would be a question of differences in shade in the photograph. If such a detection of danger can be made then one must be very cautious to make the photographs only on perfectly clear days. Otherwise, the cloud passing over makes its shadow on the water which might show on the photograph and cause uncertainty as to whether the spot is a cloud or an actual obstruction.

There are many hundreds of square miles of area along the coast that consist of salt marshes with many streams of little or no importance but which should be shown in their proper relation to other topographic features. These marshes can be photographed from aeroplanes and the streams running through them would probably show in such a way that they could be fitted into the map from the photograph. Here might be a large saving of time for the surveyor in the field.

There are other cases where there are extensive mud flats, when the tide is low, as in Jamaica Bay, New York. To survey the outline for these flats is rather laborious, with the usual instrumental methods, but it is believed that it might be possible to photograph them from an aeroplane and have the results placed on charts. It will undoubtedly be possible to get these located on the charts from aeroplane photographs with all the accuracy that is necessary for the navigator.

Location of Dangers to Navigation

In making photographs from the water, for the purpose of discovering obstructions to navigation at low tide it will be necessary to have some means to properly locate photographic features on the chart. This probably can be done by anchoring two or three small boats within the area of the photograph and locating them with relation to triangulation stations. The location could be done in the usual way in which the sounding boat is today given its position, that is by taking two sextant angles simultaneously from a boat to three control points. It can readily be seen that if two or three accurately located boats are clearly shown on the aeroplane photograph, it will be possible to place the topographic details on the map in their proper positions.

I do not wish to convey the idea that the aeroplane photography will supersede the usual methods of hydrographic surveying, but it would supplement those methods by making it possible to discover channels running through mud flats, also coral heads, shoals, and other obstructions which might be close to the surface of the water and which may be missed by the usual methods of conducting hydrographic surveying.

There has been a rather positive statement made above that the aeroplane can be used to advantage in the work of the Coast and Geodetic Survey. This is undoubtedly true but only time and the developemnt of the methods can show just how much the aeroplane can be used by this Bureau.

The Airplane In Topographic Mapping

We come now to the third class of maps and that is a subject on which I hesitate to express an opinion. That is the mapping of the interior of the country. This work is undertaken by the U. S. Geological Survey, supplemented to a certain extend by the Corps of Engineers, U. S. Army. The Coast and Geodetic Survey co-operates with those two organizations to the extent of furnishing the fundamental horizontal and vertical control for the surveys and maps but almost all of the actual location of artifical or natural features is done by the other organizations. It is understood that the officers of those two organizations have given consideration to the question of map-making by aeroplane photographs. It is hoped that aeroplane surveying can be developed at least to supplement the usual surveyors' methods in mapping the interior on a comparatively large scale map with high accuracy.

It would appear that if the aeroplane photograph will be of so much assistance in the topographic work along the shores of the country that it would really be of some value in the interior.

Whether or not it is possible to make contours from aeroplane photographs is a question that has not yet been decided. Many persons who have studied the question claim that it is impossible to locate accurately contours from aeroplane photographs. Others claim that they can be located with great accuracy. The chances are that some mean position will be found to be the true one. It is possible that the stereoscopic method can be applied to two photographs taken by two cameras on the same airplane or by cameras on two different airplanes together to obtain a rough idea of the configuration of the country.

Surveying the Interior of the Country

With regard to surveying the interior of the country for the purpose of making an accurate large scale, contoured map, I may say that here the aeroplane photographs can undoubtedly supplement the usual surveying methods, but cannot entirely supplant them.

Such a map should probably be on a 1/50 000 scale, that is one foot on the map would equal 50,000 feet on the ground, and the distance between control points on the opposite edges of the area of a map should be correct within about 1 part in 10,000. The only method by which this can be accomplished is that of triangulation and transit and tape traverse. The method today is to establish the triangulation and traverse stations ahead of the topographic surveying, with the geographic positions, that is latitude and longitude, computed on the North American or final datum. When the control points are placed on that datum their positions will not have to be changed when two maps are joined.

The control, that is triangulation and traverse, bears the same relation to the topographic mapping of the country that the steel frame work of a sky-scraper bears to the detailed portions of the building, such as walls, floors, doors, windows, etc. If the steel work is not accurately fastened and adjusted when erected, before the detailed portions are started on a building, it is reasonably certain that the building will be distorted in shape and will be structurally weak.

The same idea pertains to maps, and the difficulty mentioned actually exists today in some parts of our country, where the detailed mapping of certain areas had to precede the triangulation and traverse on the North American datum. The results have been overlaps, gaps, offsets, etc., when two maps, based on different datums have been joined together.

LATITUDES, LONGITUDES, AND ELEVATIONS NEEDED

It is the province of the Coast and Geodetic Survey to extend the fundamental control, that is latitudes and longitudes throughout the country in long arcs. These arcs are interlaced in order that the requisite strength may be obtained. This work has been carried on as vigorously as the funds at the disposal of the Survey would permit. We have arrived at a situation today which demands that this work be expedited, and it is hoped that Congress will respond to our appeals for funds in order that the work may be carried on so rapidly, that all mapping operations of federal, state, city, county, and private organizations, may have their needs met. This is a very urgent matter and I shall do my utmost to persuade the authorities to give this branch of federal surveying ample support, in order that the country may be mapped more satisfactorily and more efficiently.

When this control is available in any area, the usual method is to have surveying parties in the field place the topographic features of the maps in their proper relation to the control points. Every object on the face of the earth has one, and only one position, and it is the duty of the surveyor to place that object, whether it is a road crossing, a bridge, the top of a hill, or any other object, in its proper position on the map. On the most exact map for military purposes a well defined feature is placed on the map within 30 feet of its exact relation to the nearest control station. Other maps have larger allowable discrepancies.

The work involved in the topographic surveying consists not only in placing the features on the map in their correct horizontal positions, but it is also necessary to show by contours the lines of equal elevation, the slopes of the ground, the shapes of hills and the exact elevations of a number of critical points.

The elevations are based upon lines of levels run inward from the oceans. The surface of the ocean, if it were at rest, would be a continuous one and thus the mean position of the surface serves as a datum plane from which to measure heights in the interior of the country. More than 40,000 miles of the highest grade leveling has already been established in the interior of the country, and there are more than 20,000 precise leveling bench marks whose elevations are known within a very small portion of a foot.

In addition to the above there are many thousands of miles of leveling of a lower grade of accuracy which is used for the immediate control of the topographic surveying.

It is the duty of the Coast and Geodetic Survey to extend the lines of precise leveling into the interior of the country for the purpose of furnishing starting points for the leveling needed for the immediate use of the surveyor and engineer.

What has been said in regard to the fundamental horizontal control is also applicable to the precise leveling. Many more thousands of miles of this grade of leveling are needed in the United States today and it is hoped that my Bureau may be given the support necessary to complete that work, or so much of it as is immediately needed within the next few years.

Topographic Surveying With Plane Table

The topographic surveying is done generally by means of the plane table which consists of a tripod and certain fixtures and a plane board mounted thereon. The board is approximately 24x30 inches in horizontal dimensions. On this board is placed a sheet of paper on which the topographical features are shown. On the paper there will have been placed before going to the field, the positions of the control points, and with these as starting points, the topographer weaves a net showing the various features of the earth's surface by means of symbols. These symbols have been standardized by the map users of the United States. Any one using one of the high-grade maps should be thoroughly familiar with the symbols in order that he may make far greater use of the map than if he were ignorant of many of them.

It seems to be absolutely necessary in making the contoured survey, to do the work with the present methods. One can readily understand that it would be impossible to show contours at intervals of 20 feet (that is the difference between two contours will be that amount) over a wooded area, where trees in different parts of the forest varied in height. The aera photographed will not show the differences of elevations of trees in a wood, for the low trees and bushes not more than 20 feet in height, would show about the same on a photograph as a primitive forest where the trees may be 70 to 100 feet high.

Engineers Need Accurate Maps

The contoured map must be of such accuracy as to enable the highway engineers, and engineers engaged on irrigation projects, to lay out their work accurately. It can be readily seen that with an accurately contoured map, the engineer could plan the railway, the highway, etc. from one place to another, and not make great mistakes in grades and alignment. It is believed that this would be impossible from a contoured map made from aerophotographs. It is possible that some method may be discovered by which the differences in elevation between two points shown on each of two separate photographs can be computed, but if one considers that the work involved, if it can be done at all, will be very great, he will see that it will probably be more economical to put the contours on the map by the usual methods, than to compute innumerable elevations from photographs.

The possible method of computing distances and elevations from photographs may be supplemented by using the stereoscopic method which would give one an idea of the configuration of the ground. This would enable the draftsman in the office to select critical points whose elevations could be determined. Such critical points would be crests of hills or ridges and and the bottoms of slopes. If the elevations of critical points are determined then contours could be interpolated between them.

I am giving these statements with a good deal of reservation on my part, for the method of contouring by aeroplane photography has not been developed and it may be that very little can be accomplished where accurate contouring is desired.

AIRPLANE SUPPLEMENTS PLANE TABLE

But this accurate large-scale contoured map can undoubtedly be made by combining the usual methods of surveying with the aero-photographs. The aero-photograph will usually give a great deal of detail which may facilitate the progress of the map by the topographer using the plane table. It will be necessary of course for the topographer to select a number of definite points on his map, such as road crossings, large buildings, groups of buildings, bridges, and other features which can be identified from the photographs. Those features would serve as control points for the topographic details shown on the photographs. Without such points located by the usual methods, it would be necessary to place certain conspicuous objects on the ground near the triangulation and traverse stations. Most any kind of object that would show in the photograph, and have a distinct shape, could be used. But the placing of these objects would be expensive. It is believed that the location of the conspicuous features referred to above could be done by the topographer at a much smaller cost than the cost of placing objects for the aerophotographs, at the triangulation and traverse stations.

It is possible that the topographer would be able to place the topographic details on his map from the photographs before going into the field to do the contouring. Much of the work of the topographer by the usual methods consists in placing the topographic features on the map in their proper location, but a great deal of this might be obviated by the use of the photographs. Then he could go into the field and place the contours with greater rapidity than if he attempted to do so previous to using the details of the photographs.

AIRPLANE VALUABLE FOR MAP REVISION

What I have stated above in regard to original surveys by aero-photography, in the three classes of high grade maps, are simply opinions or prophesies. These are the coast charts, the contoured maps of the interior, and maps which show all features except contours, but I feel confident in stating that even on the highest grade of topographic maps, the aero photographs can be used to a great degree in revising and bringing up to date maps of that character which have already been made. Let us suppose that we have before us a topographic map made by the U. S. Geological Survey, say ten years ago, and let it be supposed that this map at the time it was made, was absolutely perfect. The map is supposed to show the contours, woods, streams, houses, and other features that are usually represented on such a map. In the ten years since the map was made, it is reasonably certain that some changes have been made by the works of man. It is improbable that natural features would have changed, such as streams, woods and hills, during such a short period. We may assume that new roads have been made old buildings torn down, or have burned, and new ones erected, wooded areas have been cleared, and brush or young trees may now be on areas that were bare at the time that the original survey was made. In order to test such a map and learn whether it was up to date, it would be necessary by the usual methods, to send a surveyor into the field to go over the area in great detail. Of course an inspection could be made of an area by driving over it, but many changes might be overlooked by this method of inspection.

How much simpler and more reliable it would be to send an airplane over the area in question and make a series of photographs. These photographs would show at a glance, the exact areas where changes in the features had occurred, and if the changes were not too complicated it is probable that we would be able to place the new features on the map directly from the photographs. The process would be to fit in the new features between unchanged old features, which of course would also be shown on the photographs.

PHOTOGRAPHIC PLATE SHOULD BE HORIZONTAL

In what has been said above, it has been assumed that the photographs have been made with the camera vertical, or in other words, with the photographic film or plate in a horizontal position. It is only in this way that absolutely accurate photographs could be made. If the camera is tilted from the vertical at the instant the exposure is made, then there will be a distortion of the photograph so far as the map is concerned. If this tilting were known, then the photograph could be rectified and the features shown on the map with the same accuracy as if the plate had been horizontal at the time of the exposure.

It is hoped that methods will be developed for holding the camera in a vertical position at the time of exposure. I know of none now in use which is entirely satisfactory.

CONCLUSION

I may conclude that aeroplane surveying can be done now and it undoubtedly has a bright future. Much experimentation must be done, however, before the aeroplane can be used extensively in high grade work.

I feel that the aeroplane can now furnish maps of a low order of accuracy so far as scale and position of features are concerned, which will be of considerable value in many branches of industry and commerce. They will undoubtedly be extensively used in unmapped areas in this and other countries in the very near future, in these reconnoissance surveys and maps. But I hope they may be of great use in more accurate work.

I can pledge the Coast and Geodetic Survey, so far as its limited resources will allow, to take its part in making such tests by aeroplane that may be feasible in connection with surveying and mapping.

BOOK REVIEWS

Simplicité. (A Reader of French Pronunciation). By Julius Tuckerman. New York. American Book Company. 5¼"x7¼". 128 pp. Price, $0.50.

This book is not new, having been copyrighted in 1908. The author has attempted to do something that is very difficult, for learning the pronunciation of a foreign language from a textbook on the subject is not always certain to guarantee the results desired. After all, the real and best way to learn pronunciation is to get it first hand from a well educated and careful native.

The subject matter includes first the alphabet, next, fifty lessons on pronunciation, of which six are in "liaison," two on silent letters and the rest divided among vowels, dipthongs and compounded consonants and vowels. Twenty-four pages are given to a "General Reader" and sixty-three pages to a French-English vocabulary.

The author makes the unqualified statement that the French language has twenty-six letters. Many French dictionaries and many Frenchmen agree that it has but twenty-five letters, the additional letter "w" (double ve') having been introduced to take care of certain foreign words in current usage by the French (See Spier's, Surenne's and Cassell's Dictionaries). The author has entitled his book "Simplicité" but it may be said that some of his efforts to be simple over-run the mark. Some will take exception to a few of the examples of pronunciation, as the statement that the "e" in the word "criera" is entirely silent (see page 11.) Each lesson is followed by a brief exercise illustrating the pronunciation taught therein and on the whole, these exercises are very well selected.

Forty Days in 1914. By Major Gen. Sir F. Maurice. New York. George H. Doran Co. 6"x9". 213 pp. Price, $2.00.

An interesting narrative describing the entrance into the "World War" of the British Armies, their advance into France and the heroic but heart-breaking retreat to the Marne. Finally the wonderful achievement of the British together with their allies in stopping the German advance and turning defeat into a glorious victory.

The Author has handled a most difficult task in tracing the movements of the armies in a masterly fashion displaying an intimate knowledge of his subject.

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Aerial Warfare, Great Britain. Air war against submarines. The spider web and the submarines. *The Times Weekly Review,* April 4, 1919, p. 336.

Aircraft Bombing in France. The Marine Corps Gazette, June, 1919, p. 169.

Airships, Naval. Purposes and types of naval airships. *The Journal of the Society of Automotive Engineers.* May, 1919, p. 340.

Anti-Aircraft Gunnery. The Journal of the Royal Artillery, May, 1919, p. 86.

Armies, Great Britain. Our Post Bellum Army. Organization, recruiting, etc. *The Nineteenth Century and After*, April, 1919, p. 822.

Armies, U. S. Army Organization. Mobile army by divisions. Table. *Army and Navy Register*, April 5, 1919, p. 417.

Balloons. The Balloon Observer. Methods in A.E.F. *The Field Artillery Journal*, Jan.-March, 1919, p. 56.

Chateau-Thierry. The Miracle of Chateau-Thierry. The Century, May, 1919, p. 99.

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Electric Propulsion for the U. S. S. New Mexico—II. The single-wound, variable speed motor, with double-squirrel-cage rotors of the New Mexico. *Scientific American Supplement No. 2268*, June 21, 1919, p. 396.

Electrical Gyro Compass, The. Operating principle and construction of this highly perfected electrically operated directional instrument—abstracted from lecture before American Society of Mechanical Inspectors. *Electrical Review*, June 28, 1919, p. 1079.

Evolution of the British Naval Airship, The. Engineering, June 13, 1919, p. 757.

German Submarine Diesel Engines. Engineering, June 13, 1919, p. 763.

Great Britain's Giant Bombing Plane. The Tarrant Triplane or the story of a bold experiment in airplane construction. *Scientific American*, July 5, 1919, p. 10.

Mounts for Naval Anti-Aircraft Guns. American Machinist, July 10, 1919, p. 79.

New Ships of the British Navy. Influence of the Battle of Jutland shown in the latest battleships and battle-cruisers. *Scientic American*, June 21, 1919, p. 654.

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Powders. Some characteristics of the leading military explosives. *Scientific American*, July 12, 1919, p. 33.

Suggestions for the Organization of Anti-Aircraft Artillery in the Post-Bellum Army. The Journal of the Royal Artillery, May, 1919, p. 81.

Where Should Advanced Base Organizations Be Permanently Stationed? The Marine Corps Gazette, June, 1919, p. 132.

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LIST OF BOOKS CATALOGUED AT THE LIBRARY, COAST ARTILLERY SCHOOL, DURING THE MONTH OF MAY, 1919.

Acetylene, The principles of	F. H. Leeds.
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Automobile Storage Battery	American Bureau of Engineering
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Circle and the Sphere, A treatise on	J. L. Coolidge.
College Study and College Life	Bernard C. Ewer.
Compulsory Military Service	G. G. Coulton.
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Glossary of trench warfare ordnance, A French-English & English-French	U. S. Ordnance Department.
Handy book, aid and instructions of enlisted men, engineering dept. U. S. Navy	Bruce Richardson Ware.
Hand-book of the Lewis machine gun (airplane type) mod. 1917-18 Cal. 30	Savage arm corporation.
Hand-book of the Lewis machine gun, Mod. 1917. Cal. 30	Savage arms corporation.
Hand-book of Northern France., A	William Morris Davis.
Handbook of the 37-mm gun Mod. 1916	U. S. Ordnance Department.
Hydrodynamics	Horace Lamb.
In Memoriam of General Robert Anderson	Eba Anderson Lawton.
Indicators and appliances	Crosby Steam Gage & Valve Company.
Instruction pamphlets, 1918	France, Tractor Artillery school, Vincennes.
Investigation into the cause and effects of brittleness in smokeless powder	L. L. Barrett.
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Manual for N. C. O. and Pvt., F. A., U. S. A. 1917	U. S. War Dept.
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Recruit Manual	George Cyrus Thorpe.
Reference notes for use in the course of gunnery and ammunition	U. S. Artillery School, Fort Monroe, Va.
Regulations for the Enlisted Reserve Corps	U. S. War Dept.
Regulations for government of the U. S. Navy 1913	U. S. Navy Dept.
Reports on enemy ammunition	Great Britian War office.
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JOURNAL OF THE UNITED STATES ARTILLERY

Published under supervision of the Coast Artillery Training Center Staff, by direction of the Chief of Coast Artillery.

12 numbers per year; volumes begin January and July. Issued on 15th day of each month.

Entered at the Post Office at Fortress Monroe, Va., as second class matter.

Subscription price, per annum:

Domestic	$3.00
Canada	3.25
Countries in the postal union	3.50
Single numbers	0.30

All subscriptions payable in advance.

Subscriptions may be entered to begin with any desired issue of the Journal. It is suggested that those who have not the numbers beginning with January, 1919, will find it desirable to begin with that issue, as all the numbers from there on are filled with especially live, important matter.

Make checks, drafts, and postal orders payable to JOURNAL U. S. ARTILLERY.

Remittances, articles intended for publication, and communications relating to the management should be addressed JOURNAL U. S. ARTILLERY, Fort Monroe, Virginia.

It is earnestly requested that prompt information be given of changes of address, or failure to receive the JOURNAL. Both old and new addresses should be given.

COLONEL R. R. WELSHIMER, C. A.
Manager and Editor
LIEUT. COL. F. S. CLARK, C. A.
Assistant Editor

London Agents:
B. F. Stevens and Brown, 4 Trafalgar Square

JOURNAL UNITED STATES ARTILLERY

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1919

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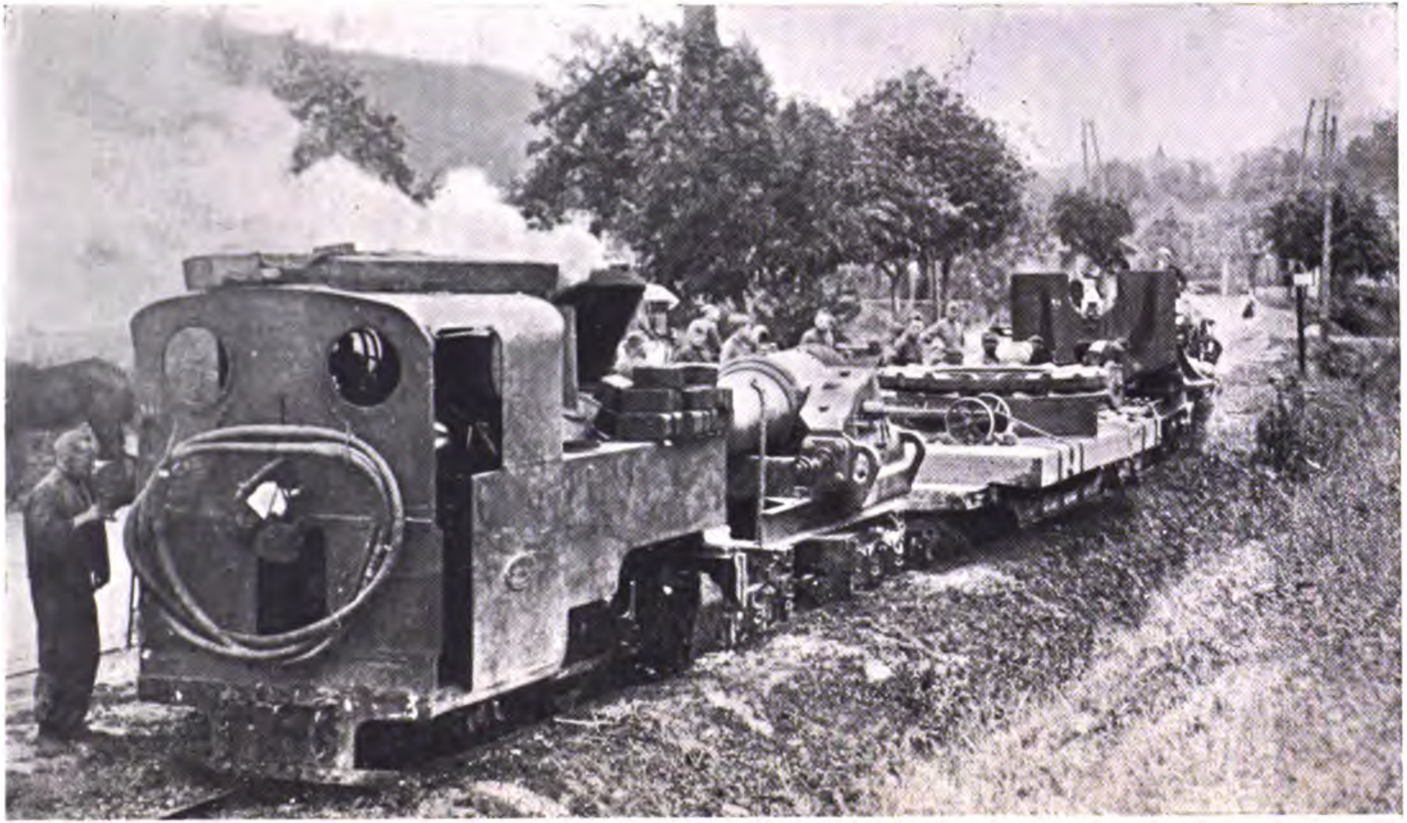

A 270 MM. MORTAR, MANNED BY 51ST ART. (C. A. C.).

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OF THE

UNITED STATES ARTILLERY

VOL. 51, No. 3. SEPTEMBER, 1919 WHOLE No. 157

The Organization and Operations of the Railway Artillery Reserve, American Expeditionary Forces

By Colonel H. C. Barnes, C. A.

The Expeditionary Brigade, Coast Artillery troops, which was the nucleus of the Railway Artillery Reserve, and the first Coast Artillery organization sent to France to participate in the Great War, was organized pursuant to instructions from the War Department dated July 6, 1917. This organization was effected at Fort Adams, Rhode Island, during the latter part of July and early part of August, 1917, under the Command of Brigadier General George T. Bartlett, U. S. A. The Brigade was composed of the Brigade Headquarters and the 6th, 7th, and 8th Provisional Regiments (C. A. C.). The organization of the Brigade was as shown in Table I.

Each of these regiments consisted of a Headquarters and Supply Company, composed largely of Enlisted Specialists, and three battalions of four batteries each. Each battery consisted of three officers and 132 enlisted men, organized with a view to manning one 10-inch gun on railroad mount; total 12 guns per regiment.

Upon completion of the organization of the Brigade in the early part of August, the movement to France was begun. The Brigade, in three Cunard Line Steamers (Andania, Aurania and Penonia), proceeded to Liverpool, England, thence, via Southampton and Le Havre, to Mailly le Camp (Aube), France, where it was assembled early in September, 1917.

TABLE I.

1 Brigadier General	Brigade Commander
1 Major, C. E.	Engineer Officer (Attached)
1 Captain, C. A. C.	Adjutant
1 Captain, C. A. C.	Ordnance Officer
1 Captain, C. A. C.	Quartermaster
1 Captain, M. C.	Sanitary Officer
2 Lieutenants, C.A.C.	Aides

A Headquarters Detachment of one Field Clerk and 17 enlisted men was also authorized.

6th Provisional Regiment, C. A. C. Afterward 51st Artillery, C. A. C.		7th Provisional Regiment, C. A. C. Afterward 52nd Artillery, C. A. C.		8th Provisional Regiment, C. A. C. Afterward 53rd Artillery, C. A. C.	
Designation of unit in regiment.	Designation of unit before joining regiment.	Designation of unit in regiment.	Designation of unit before joining regiment.	Designation of unit in regiment.	Designation of unit before joining regiment.
H & S Co.	2nd Co. Fort Mott, N.J.	H & S Co.	1st, 2d, 3d, 4th, 5th and 7th Cos. Ft. Hancock,N.J.	H & S Co.	5th Co. Fort Story, Va.
Battery "A"	1st Co. Fort McKinley, Me.	Battery "A"	1st Co. Fort H.G. Wright, N.Y.	Battery "A"	1st, 2d, 3d, & 4th Cos. Ft. Howard, Md and 1st Co. Fort Smallwood, Md.
Battery "B"	2d Co. Fort Greble, R.I.	Battery "B"	6th Co. Fort Terry, N.Y.	Battery "B"	10th Co.Fort Monroe, Va.
Battery "C"	3d Co. Fort Strong, Mass.	Battery "C"	2d Co. Fort Terry, N.Y.	Battery "C"	12th Co. Fort Monroe, Va.
Battery "D"	5th Co. Fort McKinley, Me.	Battery "D"	6th Co. Fort H.G. Wright, N.Y.	Battery "D"	11th Co.Fort Monroe, Va.
Battery "E"	1st Co. Fort Preble, Me.	Battery "E"	2d Co. Fort H.G. Wright, N.Y.	Battery "E"	3d Co. Fort Wadsworth, N.Y.
Battery "F"	4th Co. Fort Williams, Me.	Battery "F"	2nd Co. Fort Schuyler, N.Y.	Battery "F"	3d Co. Fort Hamilton, N.Y.
Battery "G"	3d Co. Fort Williams, Me.	Battery "G"	2nd Co. Fort Totten, N.Y.	Battery "G"	3d Co. Fort Tilden, N.Y.
Battery "H"	2d Co. Fort Williams, Me.	Battery "H"	6th Co. Fort Totten, N.Y.	Battery "H"	3d Co. Fort Moultrie,S.C.
Battery "I"	2d Co. Fort Andrews, Mass.	Battery "I"	4th Co. Fort Adams, R.I.	Battery "I"	1st & 2d Cos. Ft. Hunt, Va.
Battery "K"	1st Co. Fort Banks, Mass.	Battery "K"	2nd Co. Fort Adams, R.I.	Battery "K"	1st, 2d, 3d, 4th and 5th Cos. Fort Washington, Md.
Battery "L"	3d Co. Fort Andrews, Mass.	Battery "L"	6th Co. Fort Hamilton, N.Y.	Battery "L"	2d Co. Fort Caswell, N.C.
Battery "M"	4th Co. Fort Andrews, Mass.	Battery "M"	4th Co. Fort Hamilton, N.Y.	Battery "M"	2d Co. Fort Screven, Ga.

In the meantime, Brigadier General George T. Bartlett, U. S. A., was detached from the brigade and Colonel F. W. Coe, General Staff (C. A. C.) who had gone to France as Chief of Staff of the 1st Division was assigned to command the same. The latter, promoted to Brigadier General, N. A., continued in command of the brigade until relieved on May 22, 1918, when he returned to the United States to assume the duties of Chief of Coast Artillery.

The designation of the Brigade was changed to "First Separate Brigade, C. A. C." in September, 1917, and in February, 1918, the designations of the regiments comprising the brigade were changed as follows:

6th Provisional Regiment, to 51st Artillery (C. A. C.)
7th Provisional Regiment, to 52nd Artillery (C. A. C.)
8th Provisional Regiment, to 53rd Artillery (C. A. C.)

In March, 1918, the designation of the Brigade was again changed from "First Separate Brigade, C. A. C.," to "30th Artillery Brigade (C. A. C.—Railway)."

During the latter part of March and the first part of April, 1918, pursuant to instructions from G. H. Q., American E. F., there was organized a provisional regiment, designated "Howitzer Regiment, 30th Artillery Brigade (C. A. C.—Railway)." This provisional regiment, as finally organized, consisted of the Regimental Headquarters and Supply Company and four battalions of two batteries each. The organization of this regiment was effected by the transfer thereto of units of the 51st, 52nd, and 53rd Regiments as shown in Table II.

TABLE II.

Howitzer Regiment, 30th Artillery Brigade, (CAC Railway).

Designation of unit in regiment.	Designation of unit before joining regiment.
Regimental Headquarters and Supply Co.	Organized by transfers from the batteries and by assignment from other organizations and from schools.
1st Battery.	Battery "E", 52nd Artillery, C. A. C.
2nd Battery.	Battery "F", 52nd Artillery, C. A. C.
3rd Battery.	Battery "G", 52nd Artillery, C. A. C.
4th Battery.	Battery "H", 52 nd Artillery, C. A. C.
5th Battery.	Battery "I", 51st Artillery, C. A. C.
6th Battery.	Battery "K", 51st Artillery, C. A. C.
7th Battery.	Battery "E", 53rd Artillery, C. A. C.
8th Battery.	Battery "G", 53rd Artillery, C. A. C.

On April 3, 1918, the 30th Artillery Brigade (C. A. C.—Railway), comprising the 51st, 52nd, and 53rd Regiments of Heavy Artillery, American E. F., together with such auxiliary troops as were permanently assigned to the service of the Railway Artillery, was designated the "Railway Artillery Reserve, First Army, American E. F."

The 54th Artillery (C. A. C.) joined the Railway Artillery Reserve in April, 1918, and was designated as the Replacement Regiment for Heavy Artillery.

On June 24, 1918, Brigadier General William Chamberlaine, N. A., was assigned to command the "Railway Artillery Reserve and the 30th Brigade of Railway Artillery." General Chamberlaine assumed command on June 29, 1918, and remained in command of the Railway Artillery Reserve until early in January, 1919, at which time its demobilization was practically completed.

In the interval between the relief from command of Brigadier General Coe and the assumption of command by Brigadier General Chamberlaine, Colonel Malcolm Young, C. A. C., commanded the Railway Artillery Reserve by virtue of seniority.

In the latter part of July and early part of August, 1918, under instructions from G. H. Q., American E. F., the 51st, 52nd, and 53rd Artillery (C. A. C.) and the Howitzer Regiment, were re-organized into six regiments viz: the 42nd, 43rd, 51st, 52nd, 53rd, and 81st Artillery (C. A. C.). The units of the original regiments were retained in the newly organized regiments except the 2nd battalion, 51st Artillery (C. A. C.), assigned to the service of 155 G. P. F.'s, which was transferred to the 57th Artillery (C. A. C.). To replace this battalion in the Railway Artillery Reserve, batteries C and D, 57th Artillery (C. A. C.) were transferred to the 43rd Artillery (C. A. C.). At this same time and under the same authority, the 42nd, 52nd, and 53rd Artillery (C. A. C.) were assigned, and the 43rd Artillery (C. A. C.) was attached, to the 30th Artillery Brigade (C. A. C.) and the 30th Artillery Brigade (C. A. C.) and the 43rd Artillery (C. A. C.) were assigned to the Railway Artillery Reserve. The 51st and 81st Artillery (C. A. C.) were assigned to the 39th Artillery Brigade (C. A. C.), and were detached from the Railway Artillery Reserve. Later, the designation of the 81st Artillery (C. A. C.) was changed to the 44th Artillery (C. A. C.). The details of this re-organization, showing the re-assignment of the various units is shown in Table III.

On August 6, 1918, the Commanding General, Railway Artillery Reserve, was authorized to exercise within his command, the authority, powers, and functions conferred upon Division Commanders by regulations and orders. This was found necessary in order to shorten the channels of communication, reduce administrative work of intermediate Headquarters, and facilitate the transaction of business, and because it was recognized that the growth and importance of the Railway Artillery Reserve, made it appropriate that such authority, powers, and functions should be conferred upon its commander.

On September 15, 1918, pursuant to instruction from G. H. Q., American E, F., the U. S. Naval Railway Batteries, Rear Admiral C. P. Plunkett, U. S. N., commanding, was announced as a part of the Railway Artillery Reserve.

On October 10, 1918, pursuant to orders from G. H. Q., American E. F., the designation of the Railway Artillery Reserve, First Army, American E. F., was changed to Rail-

TABLE III.

30th Artillery Brigade, (C. A. C.) Brigade Headquarters Detachments organized by transfers and from replacements.					
42d Artillery, (C. A. C.)		52d Artillery, (C. A. C.)		53d Artillery, (C. A. C.)	
Designation of unit in regiment.	Designation of unit before joining regiment.	Designation of unit in regiment.	Designation of unit before joining regiment.	Designation of unit in regiment.	Designation of unit before joining regiment.
Regt. Hdqrs. Detachment.	From H & S Co. 52d Arty CAC and by transfers.	Regt. Hdqrs. Detachment.	From H & S Co. 53d Arty CAC and by transfers.	Regt. Hdqrs. Detachment.	From H & S Co. 53d Arty CAC and by transfers.
Bn. Hdqrs. Detachment. 1st Bn.	By transfers	Bn. Hdqrs. Detachment. 1st Bn.	By transfers	Bn. Hdqrs. Detachment. 1st Bn.	By transfers
Battery "A"	Btry I, 52d Arty, C.A.C.	Battery "A"	Btry A, 52d Arty, C.A.C.	Battery "A"	Btry A, 53d Arty, C.A.C.
Battery "B"	Btry, K 52d Arty, C.A.C.	Battery "B"	Btry B, 52d Arty, C.A.C.	Battery "B"	Btry B, 53d Arty, C.A.C.
Bn. Hdqrs. Detachment. 2nd Bn.	By transfers	Bn Hdqrs. Detachment. 2nd Bn.	By transfers	Bn. Hdqrs. Detachment. 2nd Bn.	By transfers
Battery "C"	Btry L, 52d Arty, C.A.C.	Battery "C"	Btry C, 52d Arty, C.A.C.	Battery "C"	Btry C, 53d Arty, C.A.C.
Battery "D"	Btry M, 52d Arty, C.A.C.	Battery "D"	Btry D, 52d Arty, C.A.C.	Battery "D"	Btry D, 53d Arty, C.A.C.
Bn. Hdqrs. Detachment. 3rd Bn.	By transfers	Bn. Hdqrs. Detachment. 3rd Bn.	By transfers	Bn. Hdqrs. Detachment. 3rd Bn.	By transfers
Battery "E"	Btry H, 53d Arty, C.A.C.	Battery "E"	Btry I, 53d Arty, C.A.C.	Battery "E"	Btry L, 53d Arty, C.A.C.
Battery "F"	Btry F, 53d Arty, C.A.C.	Battery "F"	Btry K, 53d Arty, C.A.C.	Battery "F"	Btry M, 53d Arty, C.A.C.

TABLE III. (Continued)

39th Artillery Brigade, CAC.

Brigade Headquarters Detachment organized by transfers and replacements.

44th Artillery, C. A. C.		51st Artillery, C. A. C.	
Designation of unit in regiment.	Designation of unit before joining regiment.	Designation of unit in regiment.	Designation of unit before joining regiment.
Regt. Hdqrs: Hdqrs. Company and Supply Company.	From personnel of H & S Co. and Supply Co. of Howitzer Regt, 30th Artillery Brigade (CAC-Ry).	Regt. Hdqrs; Hdqrs. Company and Supply Company.	From personnel of H & S Co. 51st Artillery CAC and Det. H & S Co. of Howitzer Regiment attached to 4th Bn. Howitzer Rgt.
Battery "A".	3rd Battery, Howitzer Regiment.	Battery "A".	Battery "A", 51st Artillery, C. A. C.
Battery "B".	4th Battery, Howitzer Regiment.	Battery "B".	Battery "B", 51st Artillery, C. A. C.
Battery "C".	5th Battery, Howitzer Regiment.	Battery "C".	Battery "L", 51st Artillery, C. A. C.
Battery "D".	6th Battery, Howitzer Regiment.	Battery "D".	Battery "M", 51st Artillery, C. A. C.
Battery "E".	1st Battery, Howitzer Regiment.	Battery "E".	7th Battery, Howitzer Regiment.
Battery "F".	2nd Battery, Howitzer Regiment.	Battery "F".	8th Battery, Howitzer Regiment.

TABLE III. (Continued)

Attached to 30th Artillery Brigade, (CAC)	
43d Artillery, (C. A. C.)	
Designation of unit in regiment.	Designation of unit before joining regiment.
Regt. Hdqrs. Detach.	By transfers.
Bn. Hdqrs. Detach. 1st Battalion	From personnel attached to Hq. 2nd Bn. 57th Arty, CAC.
Battery "A".	Battery C, 57th Arty, C. A. C.
Battery "B".	Battery D, 57th Arty, C. A. C.
Bn. Hdqrs. Detach. 2nd Battalion.	By transfers.
Battery "C".	Battery C, 51st Arty, C. A. C.
Battery "D".	Battery D, 51st Arty, C. A. C.
Bn. Hdqrs. Detach. 3rd Battalion.	By transfers.
Battery "E".	Battery E, 51st Arty, C. A. C.
Battery "F".	Battery H, 51st Arty, C. A. C.

way Artillery Reserve, American E. F. This removed the Railway Artillery Reserve from the First Army and placed it under the direct command of General Headquarters.

On October 21, 1918, Colonel H. C. Barnes, C. A., was assigned to command the 30th Artillery Brigade (C. A. C.). On November 9, 1918, Colonel Barnes was relieved and Brigadier General Johnson Hagood, N. A., was assigned to command the same. General Hagood assumed command of the Brigade on November 17, 1918. Colonel F. C. Jewell, G. S., was in command of this Brigade from October 30, 1918, to November 17, 1918, during the absence on leave of Colonel Barnes.

On October 21, 1918, Brigadier General H. J. Hatch, N. A., was assigned to command the 40th Artillery Brigade (C. A. C.). General Hatch remained in command of this Brigade until in December, 1918, when the Brigade was demobilized and General Hatch returned to the United States.

During the latter part of October, 1918, the following organizations arrived in France from the United States and joined the Railway Artillery Reserve at Mailly le Camp (Aube):

Headquarters 40th Brigade (C. A. C.)
73rd Artillery (C. A. C.)
74th Artillery (C. A. C.)

Advance school detachments from the 75th Artillery (C. A. C.) also joined during the latter part of October, 1918, but, due to the cessation of hositilities, the rest of this regiment, which had been detailed on temporary duty with the S. O. S., never joined the Railway Artillery Reserve.

During the existence of the Railway Artillery Reserve, the following auxiliary units were either organized within the command or were assigned to it:

Railway Artillery Supply Dept., American E. F.
Military Police Detachment.
Motor Transport Detachment.
Railway Artillery Repair Shop.
First Provisional High Burst Range Section.
First Railway Artillery Operation Battalion A. S. C.
First Railway Artillery Construction Battalion A.S.C.
Organization and Training Center No. 6, including the Railway Artillery Specialists' School.

The armament manned by the units of the Railway Artillery Reserve, American E. F., at the date of the signing of the armistice (November 11, 1918) is shown in Table IV.

TABLE IV.

RAILWAY ARTILLERY RESERVE MATÉRIELS

30th Artillery Brigade, C. A. C.

	42nd Art. (C. A. C.)	52nd Art. (C. A. C.)	53rd Art. (C. A. C.)	43rd Art. (C. A. C.)
1st Bn.	24G ǀ ǀ ǀ ǀ ǀ ǀ ǀ ǀ	32 c.m. ǀ ǀ ǀ ǀ	400mm. 340mm. ǀ ǀ ǀ	19G ǀ ǀ ǀ ǀ ǀ ǀ ǀ ǀ (Platform)
2nd Bn.	24G ǀ ǀ ǀ ǀ ǀ ǀ ǀ ǀ	32 c.m. ǀ ǀ ǀ ǀ	400mm. 340mm. ǀ ǀ ǀ	No matériels available for assignments.
3rd Bn.	19G ǀ ǀ ǀ ǀ ǀ ǀ ǀ ǀ	32 c.m. ǀ ǀ ǀ ǀ	19G ǀ ǀ ǀ ǀ ǀ ǀ ǀ ǀ (Platform)	19G ǀ ǀ ǀ ǀ ǀ ǀ ǀ ǀ (Platform)

40th Artillery Brigade, C. A. C.

73rd Art. (C. A. C.)	74th Art. (C. A. C.)	75th Art. (C. A. C.)
Organized to mann 10 or 12 U. S. Railway No matériels yet available in France for assignment.	Organized to mann 8 in. U. S. Railway. No matériels yet available in France for assignment.	Organized to mann 10 or 12-in. U. S. Railway. No matériels yet available in France for assignment.
ǀ ǀ ǀ ǀ ǀ	U. S. Naval Railway Batteries.	

TABLE IV. *(Continued)*

RECAPITULATION

	Pieces	Pieces	Total
42nd Art. (C.A.C.)	24		
52nd Art. (C.A.C.)	12		
53rd Art. (C.A.C.)	14		
43rd Art. (C.A.C.)	16		
30th Art. Brigade (C.A.C.)		66	
73rd Art. (C.A.C.)	0		
74th Art. (C.A.C.)	0		
75th Art. (C.A.C.)	0		
40th Art. Brigade (C.A.C.)		0	
U. S. Naval Railway Battalion		5	
Railway Artillery Reserve			71

The activities of the Railway Artillery Reserve, under its various designations, were many and varied, consisting principally of the gradual organization, development, and service of American Railway Artillery in France. In addition to this, however, the early development and primary organization of Tractor Artillery of the American E. F. was effected under the supervision of the Commanding General and his Staff, the first six battalions (one battalion, 155mm. G. P. F.—one battalion 240 mm., St Chaumond, and four battalions of 8-inch howitzers) being organized from units of this command, trained and sent to the front. Also a large percentage of the instructional personnel, including the directors of instruction, for the Tractor Organization and Training Centers in France, were furnished from this command. The Heavy Artillery Board, American E. F., was originally established as an auxiliary of the Railway Artillery Reserve and functioned as such until its removal to Angers early in July, 1918, when it was placed directly under the Chief of Artillery, American E. F. The Heavy Artillery School, American E. F., although never strictly a part of the Railway Artillery Reserve, was, until July, 1918, under the command of the Commanding General, Railway Artillery Reserve. Instructional personnel for this school was furnished entirely from this command until July, 1918, when the school was removed to Angers.

From a small brigade headquaters and three regiments, as shown in Table I, the command gradually grew larger as its activities grew broader, until, at the time of demobilization it consisted of the following organizations:

Railway Artillery Reserve, A. E. F. Headquarters Staff.
Railway Artillery Supply Depot, A. E. F.
Military Police Detachment.
Motor Transport Service Detachment.
Railway Artillery Repair Shop.
1st Provisional High Burst Ranging Section, R. A. R.
1st Railway Artillery Operation Battalion, A. S. C.
1st Railway Artillery Construction Battalion, A. S. C.
Organization and Training Center No. 6, including the Railway Artillery Specialists' School.
Railway Artillery Replacement Battalion.
30th Artillery Brigade (CAC)
  42nd Artillery (CAC)
  52nd Artillery (CAC)
  53rd Artillery (CAC)
  43rd Artillery (CAC) (Attached)
40th Artillery Brigade (CAC)
  73rd Artillery (CAC)
  74th Artillery (CAC)
  75th Artillery (CAC) (Advanced School Detachment only)
U. S. Naval Railway Batteries.

The following organizations, not a part of the Railway Artillery Reserve at the date of its demobilization, were a part thereof until separated therefrom in August, 1918:

44th Artillery (CAC)
51st Artillery (CAC)
1st Battalion, 57th Artillery (CAC)

These organizations constituted the original Tractor Artillery of the American E. F. above mentioned.

The authorized organization of the Headquarters for the proper administration and supply of this Command and for the proper supervision of the operations of the units composing the same, was increased from time to time as changing conditions necessitated and was, on June 15, 1918, under Organization Table entitled: "Provisional Replacement Unit, Type "F", as follows:

Railway Artillery Reserve, Headquarters:
  1 Brigadier General
  2 Lieutenants (Aides)

1 Colonel
4 Lieutenant Colonels or Majors
4 Majors or Captains
2 Captains
3 Lieutenants
4 Field Clerks
46 Enlisted men

Railway Artillery Supply Depot, A. E. F.:
1 Lieutenant Colonel or Major
3 Majors or Captains
4 Captains
12 Lieutenants
3 Field Clerks
247 Enlisted men

Military Police Detachment:
1 Major or Captain
2 Lieutenants
149 Enlisted men

Motor Transport Service Detachment:
3 Captains
7 Lieutenants
241 Enlisted men

Total for Railway Artillery Reserve Headquarters:
1 Brigadier General
2 Aides-de-Camp
1 Colonel
5 Lieutenant Colonels or Majors
8 Majors or Captains
9 Captains
24 Lieutenants
7 Field Clerks
683 Enlisted men

The authorized Railway Artillery Reserve Staff was further augmented by authority from GHQ, American E. F., G-3, August 8, 1918, as follows:

FOR GENERAL STAFF DUTIES

Chief of Staff	Colonel, General Staff

1st SECTION (G-1):

1 Major	Coast Artillery Corps
1 Captain	Coast Artillery Corps

2nd Section (G-2):

1 Major	Coast Artillery Corps
1 Major	Engineer Corps (Orienteur Officer)
1 Captain	Coast Artillery Corps
1 Captain	Engineer Corps (Orienteur Officer)

3rd Section (G-3):

1 Colonel	Coast Artillery Corps
2 Lieut. Colonels	Coast Artillery Corps
6 Majors	Coast Artillery Corps
6 Captains	Coast Artillery Corps

4th Section (G-4):

1 Lieut. Colonel	Coast Artillery Corps
1 Major	Coast Artillery Corps (Ordnance)
1 Major	Coast Artillery Corps (Motor Transportation)
1 Major	Coast Artillery Corps (Quartermaster Supplies)
1 Major	Engineer Corps (Railway location & construction)
1 Major	Engineer Corps (Railway operation & repair)
1 Major	Signal Corps
1 Captain	Engineer Corps (Camouflage)

5th Section (G-5):

1 Lieutenant Colonel,	Coast Artillery Corps
2 Majors	Coast Artillery Corps

Administrative Staff:

1 Major	Coast Artillery Corps (Adjutant)
1 Major	Inspector General's Dept. or Acting Inspector General.
1 Major	Judge Advocate's Department
1 Major	Medical Corps (Sanitary Inspector)
1 Major	Coast Artillery Corps (Gas Officer)

Such statistical personnel as may be necessary.

These officers were authorized in addition to those previously allowed for the Supply Depot, Military Police, and Motor Transport Detachment in the Tables of Organization for Provisional Replacement Unit, Type F.

These allowances and the distribution of staff officers shown was tentative and the Commanding General, Railway Artillery Reserve, was authorized to make such changes in the distribution of duties as experience dictated to be advisable. He was instructed to submit, after his staff had been organized, trained, and had functioned for a reasonable time, his recommendations as to its permanent organization in order that it might then be given a definite status.

The Commanding General, Railway Artillery Reserve, was instructed to cause the officers assigned to G-3 to be given an intensive course of training to the end that each officer of this section might be competent to prepare detailed plans for the tactical employment of units of the Railway Artillery Reserve. It was the stated policy of GHQ, American E. F. that officers of this section would be available for duty as the Railway Artillery Reserve representatives on the Staff of the Chief of Artillery of Armies, that such officers would not be permanently assigned to Armies, but that when units of the Railway Artillery Reserve were assigned to an Army for tactical employment, the Commanding General, Railway Artillery Reserve, would be directed to designate a sufficient number of staff officers for temporary duty with the Army to assist in the preparation of the detailed operation plans and that as soon as their missions were accomplished, they were to be returned to the Headquarters, Railway Artillery Reserve and to be available for assignment elsewhere.

This organization of the Staff, as stated above, was tentative and was based on the best information then obtainable and after conference between a representative of G-3, GHQ, a representative of the Chief of Artillery, First Army, A. E. F. and the commanding General, Railway Artillery Reserve. It was intended to furnish, in addition to the Staff proper of the Railway Artillery Reserve, a corps of officers properly instructed in the operation of the Railway Artillery, to serve as advisors in such matters to Army Artillery Commanders and sufficient for three Armies.

On August 19, 1918, pursuant to instructions from the Chief of Artillery, First Army, American E. F., the Commanding General, Railway Artillery Reserve, proceeded in person with a small staff to establish an "Advance Echelon" of the Railway Artillery Reserve Headquarters at Coussey (Vosges), in the vicinity of the Headquarters, 1st Echelon, Army Artillery, 1st Army, American E. F. These Headquarters were established with a view to participating in the operations of the 1st Army, American E. F., which had taken over from the French the sector of the front from the Moselle to Fresnes.

In compliance with these instructions, the Commanding General, Railway Artillery Reserve, exercised, from his First Echelon Headquarters, command of the Railway Artillery of the 1st Army, American E. F. This constituted a departure from the policy previously outlined when the Railway Artillery Reserve Staff was last re-organized. The duties of the Commander of the Railway Artillery in the 1st Army, American E. F., were at this time defined by the following extract from a memorandum issued from Headquarters, Army Artillery 1st Army, American E. F.:

"First Echelon, Headquarters Railway Artillery Reserve.

(a) Prepares, for the approval of the Chief of Artillery, detailed plans for the use of the Railway Artillery, these plans to be based upon the general artillery plan.

(b) Prepares drafts of orders and instructions for the execution of the approved plans for use of Railway Artillery, and supervises their execution.

(c) Transmits to Railway Artillery Reserve units the tactical orders directed by the Chief of Artillery, 1st Army.

(d) Makes reconnaissances of and selects positions for Railway Artillery matériel.

(e) Supervises the billeting, occupation of garages, and the movement of all Railway Artillery trains.

(f) Makes recommendations as to allotment of ammunition for Railway Artillery.

(g) Assists in tactical and technical inspections of Railway Artillery materiel and personnel.

(h) Maintains close liaison, insofar as concerns the Railway Artillery, with the Operations, Information, Ordnance, Signal, and Engineer Sections of the Army Artillery Staff.

(i) Insures liaison between the operations of the Railway Artillery units attached to the 1st Army and the Commanding General, Railway Artillery Reserve."

Up to this time, it was the opinion of all those who had given the matter consideration, that a certain number of officers from G-3, Railway Artillery Reserve Staff, should be attached for duty to the Staff of the Chief of Artillery of each Army for the purpose of performing the necessary staff functions in regard to the operations of Railway Artillery attached to the Army. When the 1st American Army began to operate as an Army, however, it was soon found that the many and varied details requiring prompt and careful attention were such as to necessitate one officer of superior rank to command all the Railway Artillery attached to the Army and to direct their operations, this officer to act under instructions from the Army Artillery Commander and to be provided with a proper Staff to handle the details.

The duties of this officer were later outlined as follows:

(a) To act as advisor to the Army Artillery Commander in matters concerning the use and operation of Railway Artillery in the Army.

(b) To collect all information regarding the possible use of Railway Artillery in the Army Sector, to keep records of the same and to keep the Army Artillery Commander advised concerning the same.

(c) Under the direction of the Army Artillery Commander' to maintain a continuing study of the possibilities for the use of Railway Artillery in the Army Sector, for the extension of existing firing epis, etc., both in the Sector as it exists, and in a case of an advance or retirement (dressing the front); and from time to time, to make recommendations to the Army Artillery Commander looking to the improvement of these conditions.

(d) Under the direction of the Army Artillery Commander, to prepare plans for the use of Railway Artillery for offensive and defensive action within the Army Sector, including their organization into sub-groupings. (These plans, after approval by the Army Artillery Commander, to be forwarded through the Commanding General, Railway Artillery Reserve, to G. H. Q., and to form the basis for the assignment to the Army of such elements of Railway Artillery as would be required to perform the mission).

(e) Under the direction of the Army Artillery Commander, to command all elements of Railway Artillery attached to the Army for employment.

(f) To prepare firing programs covering the firing to be done by the elements of the Railway Artillery in the Army (these programs to be based on the orders issued by the Army Artillery Commander); and to supervise the execution of the same.

(g) Under the direction of the Army Artillery Commander, to supervise and direct the operations of the Railway Operation Battery in the Army Sector.

(h) Under the direction of the Army Artillery Commander, to supervise and direct the operations of the organization provided for hauling ammunition for all Railway Artillery armament in the Army.

(i) Under the direction of the Army Artillery Commander, to supervise and direct the operations of the Railroad Construction Troops attached to the Army for the purpose of constructing firing epis, access tracks, etc.

(j) To render to the Army Artillery Commander, or other proper authority, such reports as may be required concerning the operations of the Railway Artillery in the Army Sector.

(k) To exercise, under the Commanding General, Railway Artillery Reserve, such functions concerning the administration and supply of the Railway Artillery units as may be necessary during the period of their attachment to the Army.

The staff maintained at the 1st Echelon, Railway Artillery Reserve, was from time to time changed to meet the conditions until it was believed that a suitable staff, that is, one properly organized to handle the work, had been developed. It was then found that in practically all essentials, this staff was the same as that authorized for a "Heavy Artillery Brigade," the only essential difference being that one or more officers from G-3, Railway Artillery Reserve, should be attached for the purpose of having immediate direction under the Brigade Commader, of the operations, the number of such officers so attached being governed by the activities of the Army at any given time. As the Railway Artillery Reserve at this time included in its organization two Brigade Headquarters (30th and 40th Brigades, CAC), the Headquarters of the 30th Artillery Brigade, CAC, joined the 1st Army, American E. F., on October 13, 1918, and replaced the 1st Echelon, Railway Artillery Reserve, and the 2nd Army, American E.F., being in process of formation, the Headquarters of the 40th Artillery Brigade, CAC, joined that Army about October 31, 1918.

It was the plan of the Commanding General, Railway Artillery Reserve, American E. F., that there should be assigned to each Army, one Brigade Headquarters from the Railway Artillery Reserve. This Headquarters was to form a permanent part of the Army to which it was assigned and was to be the office of record for all matters concerning Railway Artillery in that Army. Since the conditions surrounding and governing the use of Railway Artillery, in the Army Sector, required a continuing study, looking to the extension of the necessary army railroads, construction of new epis, access tracks, etc., the permanent assignment of such a Headquarters was believed to be necessary. The number of troops of the Railway Artillery assigned to an Army would necessarily vary from time to time, depending upon the activity of the Army, and, undoubtedly, during quiet periods, these numbers would be reduced below that which would constitute an appropriate command for a Brigadier General. However, during such periods, the importance of the studies to be made and construction work involved were considered of sufficient importance to justify the retention on duty in the Army Sector of a Brigadier General with his Headquarters.

The cessation of hostilities prevented further study or development along this line.

From August 19 to November 11, 1918, the 1st Echelon, Railway Artillery Reserve, afterwards the Headquarters, 30th Artillery Brigade, C. A. C., took part in the St. Mihiel and Argonne-Meuse operations.

During the St. Mihiel operation, the organization comprising the Railway Artillery command consisted of one Railway Operation Battery, one Railway Construction Battery, and three Railway Groupings (total of 22 Batteries and 64 guns of calibers from 19 cm. to 400 mm.).

A total of 2110 rounds were fired by the command for counter-battery, interdiction, harassing and destruction purposes against enemy targets.

During the Argonne-Meuse operation, the organizations comprising the Railway Artillery command, consisted of one Railway Operation Battery, Detachment Railway Artillery Motor Transport Service, Special Meteorological Station for Long Range Firing, 1st Provisional High Burst Ranging Section and two Railway Sub-Groupings (total 21 batteries and 41 guns of calibers from 19 cm. to 400 mm.). A total of 13,227 rounds were fired by the command for counter-battery, interdiction, harrassing and destruction purposes against enemy targets.

The Headquarters, 40th Artillery Brigade, CAC, had made plans for the use of Railway Artillery in a contemplated offensive in the sector of the Second Army, American E. F., and the units were being assembled, when further activities were stopped by the cessation of hostilities. Three hundred rounds were fired by one of the units of this command on the morning of November 11, 1918.

The following facts regarding certain units of the Railway Artillery Reserve, American E. F. are of interest:

The first troops of the Railway Artillery Reserve to participate in active operations against the enemy, consisted of the Headquarters 3rd Battalion, and Batteries "H" and "I", 53rd Artillery, CAC, and Batteries "L" and "M", 52nd Artillery, CAC. In the later re-organization, these units became respectively, Headquarters 3rd Battalion, 52nd Artillery, CAC, Battery "E" 42nd, Battery "E" 52nd, and Batteries "C" and "D", 42nd. These units participated in a Coup de Main by the IV French Army, Februray 10-14, 1918. The batteries all manned 32 cm. Glissement (French) Railway guns, Model 1870-81. One battery received its armament on November 7, 1917, the others all received theirs on December 28, 1917. When it is considered that these guns were totally different weapons from anything known to the American Coast Artillery Corps before their arrival in France, it must be conceded that a remarkable record was made by these organizations, which received their armament December 28, 1917, and were actively engaged at the front, February 13, 1918, after but 47 days training with their new armament.

Battery "E", 42nd Artillery, CAC, (then Battery "H", 53rd Artillery, CAC) is credited with firing the first shell fired by the Railway Artillery, American E. F., on the Western front. This shell was fired on February 13, 1918.

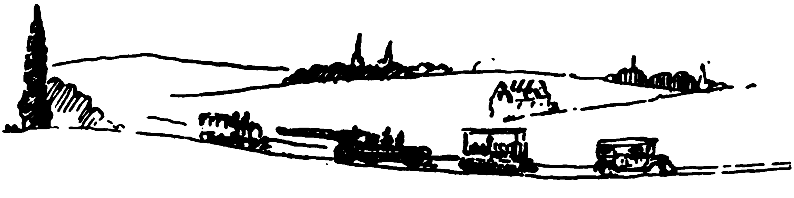
The Commanding Officer, 3rd Battalion, 52nd Artillery, CAC., (Batteries "E" and "F"), received a letter from Commandant Pichelin of the IV French Army bestowing the congratulations of the General in Command of the Artillery of the IV French Army for the efficient help contributed by this group. He also received a letter from Lieutenant Colonel Bourgain, Commander of the Grouping, of which this Group was a part, thanking him for the excellent shooting of this Group, particularly the firing on the Manre Tunnel, which fire resulted in the complete destruction of the Tunnel. The enemy was bringing re-enforcements through this tunnel and throwing them against the advancing Allied infantry. The closing of the tunnel enabled the Allied infantry to take and hold valuable ground.

In addition to manning the 32 cm. guns assigned to it, Battery "E", 52nd Artillery, CAC, was trained in the service of 105 mm. (French) guns, and 155 mm. (French, Schneider shorts) and fired on enemy positions with these calibers on August 24 and 28, 1918.

In addition to manning the 32 cm. guns assigned to it, Battery "F", 52nd Artillery, CAC, received instruction in the service of 105 mm. (French) guns from August 9-16, 1918, the battery officers and 37 enlisted men having manned a four gun battery of this caliber near Courtemont and having fired 14 rounds per gun against the enemy. This battery was also instructed in the service of 155 mm. (French, Schneider shorts) September 6-11, 1918, the battery officers and 40 enlisted men having manned a four gun battery of this caliber near Courtemont and having fired 33 rounds on September 12, 1918.

While occupying a position near Regneville on October 27, 1918, Battery "A", 43rd Artillery, CAC, was commended by its Regimental Commander for continuing to man and operate its guns under intense enemy shell fire.

Battery "H", 43rd Artillery CAC, was commended in letters from its Group and Groupings Headquarters for conspicuous conduct under immediate shell fire on October 27, 1918.



The Coast Artillery and the Reserve Officers' Training Corps

By Major Harrison Tilghman, Coast Artillery

Editor's Note. The Society for the Promotion of Engineering Education held its twenty-seventh annual meeting at The Johns Hopkins University Homewood, Baltimore, Maryland, June 25-28, 1919. Representatives from many of the prominent engineering schools were present.

In a number of *Engineering Education*, the Journal of the Society, published shortly before the Baltimore meeting, it was stated that the general topic of the meeting would be "What changes should be made in engineering education as the result of what we learned and experienced during the war?" The topic indicates clearly that some change which would produce a graduate better prepared to meet the issue of war is desirable. The War Department believes that this result can be accomplished through the R. O. T. C.

Engineering Education, in a further reference to the annual meeting, stated, "There are still a great many questions of policy which must be settled before the exact relation of engineering schools to the R. O. T. C. can be determined." This relation was thoroughly discussed at the convention.

Among the papers presented before the convention were two by Army officers. First "Military Training in Engineering Schools, by Col. F. J. Morrow, G. S., Chairman, Committee on Education and Special Training of the War Department, and second, that of Major Tilghman which is here printed.

In the opinion of the officers attending the convention, the engineering schools are very willing to assist the R. O. T. C. movement but will not accept a program which will divert the student from the studies of his life's work.

Mr. President and members of The Society for the Promotion of Engineering Education:

Some several weeks ago, the society through its secretary, Dr. Bishop, kindly extended me an invitation to attend this convention.

I had hoped that I might come to listen rather than to talk. However, Dr. Bishop also invited me to take part in the discussion and while I feel some hesitancy in addressing so distinguished a gathering, I hope that as a worker in the mutual field my temerity will be pardoned.

Colonel Morrow has already discussed in most interesting fashion the subject of "Military Training in Engineering Schools," and while my own subject "The Coast Artillery and the Reserve Officers' Training Corps," is more restricted, I feel that I must touch, to some extent at least, on the more general subject of the Reserve Officers' Training Corps, its reasons for being, and the results expected from it.

There are many theories of government, each of which when in control of a nation, determines its military policy. But one policy makes for security in peace and success in war; it is that one which will provide superiority in the theater of operations. The War Department is confronted with the necessity of making preparation for war with such means as the government will supply.

As between men, so between nations; good will is the best of assets, but potential strength receives deference during the course of argument, and superior strength gains the final decision.

At the time of the establishment of our country, the Americans were a small but homogenous people accustomed to self government and individual liberty. So jealous were they of these rights that the country itself was born in resistance to encroachment upon them. It is needless to add that it was force and not persuasion which accomplished the happy outcome. It is for us to preserve these rights. To do so we must be prepared to use the same means as were successful in their establishment.

In establishing our government our forefathers wisely decided upon a republican form. Now an intelligent electorate is the necessary foundation of a republic, for in a republic, the policy of the government flows directly from the ability of the average elector to pass judgment upon the issue. Therefore the preservation and future progress of our country is more completely determined by the education of its youth than by any other factor. It is in the hands of men such as those composing this society that the future of the country primarily rests.

But one may ask, "How does all this concern the Reserve Officers' Training Corps?" I answer: In two ways. First, those who would preserve their liberties must know them; and second, they must be able to protect them.

The R.O.T.C. exists to produce a citizenry of this character and for no other purpose.

Although there are many brilliant examples of success in the absence of a collegiate education, in general the college man is undoubtedly the leader in all fields and will become more and more so as the field of the pioneer in industry becomes circumscribed, and the general standard of education rises. We must look to the colleges for our leaders in both peace and war.

Recently we have beheld the spectacle of this country engaged, in spite of its own great forbearance, in war against an aggressive enemy. Fortune favored us in that we were able to prepare for the encounter behind the shield of the allies. But so unprepared were we when we entered the fight that more than a year elapsed before we became an active participant. Those who believed and preached that a million men would spring to the defense of the country overnight had their dream rudely shattered. There were neither the arms to spring to, nor had the men been trained to do the springing. Military service is like any other endeavor. Training must precede performance, and while we trained, it is no secret, that grave apprehension was felt that an adverse decision might be reached in Europe before our forces became available. Those who were in France during the spring of 1918 know this but too well.

Many men strange to the uniform in April, 1917, made brilliant records as officers during the course of the war, bringing honor to themselves, the army, and their country. But they owe the opportunity to receive the necessary training to the strong wall of the allies.

Friendships are relatively as valuable to nations as they are to men. Our country has recently made many and we hope will by all means permanently preserve them. But neither nations nor men can trade upon, and preserve friendships.

Time is of the essence in war, and a successful military policy can not be based upon tardy preparation. America should always be ready to prevent war by readiness for it and in any alliance or league to do her full share from the first.

The Reserve Officers' Training Corps is a great and very necessary step in this direction. It is a fitting thing that, while preparing for his life's work, a student should also be learning his rights, and how to perform his duties as a citizen. Not the least of his duties is the protection of his country. The Reserve Officers' Training Corps will train the student so that upon graduation, he will stand ready to take his place as a junior officer in the army, and take it immediately.

Yesterday Dr. Goodnow spoke of the necessity of an education which will allow its possessors to evaluate correctly—perhaps no one is really educated whose training has not taken that form—let his specialized knowledge be what it will.

Let us evaluate correctly. I was much interested in the fourth resolution presented to the society by the special committee; which after rejecting a reference to courses which will develop effective citizenship, was finally adapted in the form:

"That engineering students be required to pursue courses which will develop their business and administrative qualities."

While the rejection of reference to effective citizenship was based on the ground that present courses do make for effective citizenship; has not the society placed itself on record as holding that while something is now lacking in the business and administrative qualities of the graduate, nothing is lacking in his effective citizenship? It seems to me that this flows directly from the action, and that the view is false.

To quote from the report of the special committee "We are apt to oppose a new pedagogic proposition because we feel it will not work well under our own particular conditions." Might it not be also that lack of familiarity with just what is proposed may cause opposition?

The R.O.T.C. movement proposes to train a student in the full duties of citizenship, with a minimum of interference with his life's work. To do this the unit will be adapted to the institution rather than the institution to the unit.

I now find myself in somewhat of a quandary, for the proposition which will be placed before educational institutions by the War Department has not been definitely established. In general, it is proposed so to place R. O. T. C. units that not more than two branches of the service will be represented in any institution and that there will be a proper military distribution of the 50,000 reserve officers which will be raised.

Within these limitations, the type of unit placed in an institution will be that which the institution is best fitted to receive. It is further proposed to give a basic course in military training during the first year and work of increasing specialization during the following years. All of these provisions are undoubtedly sound.

The Coast Artillery is that branch of the military service which mans the guns (both rifles and mortars of large caliber) and submarine mines of our harbor defenses. It also mans the larger guns, both tractor drawn and railway mounted, which accompany an army in the field. Several other specialties, including the trench mortar and anti-aircraft armament, are manned by Coast Artillery troops.

Probably the Railway Artillery Reserve, American Expeditionary Forces, first commanded in action by Brigadier General F. W. Coe, now Major General and Chief of Coast Artillery; and afterwards until the close of the war by Brigadier General William Chamberlaine, now Commanding General, Coast Artillery Training Center, Fort Monroe, Virginia, had the most extensive service at the front of any of our artillery commands. Its guns were first in action during the winter of 1917 - 18 and thereafter continuously until the armistice. They were in position from Alsace to the British front and served with both the American and French armies. All units of the Railway Artillery Reserve, excepting a Naval contingent which joined in the summer of 1918, were drawn from the Coast Artillery Corps.

The Coast Artillery officer requires the general culture common to all arms of the service. He must also be an engineer, skilled primarily in the principles of civil and also in those of mechanical and electrical engineering. Therefore, the engineering student must closely conform to the requirements for a Coast Artillery officer and Coast Artillery instruction is best given in engineering institutions.

With this fact in mind, the Chief of Coast Artillery has already approved of the establishment of twenty Coast Artillery R.O.T.C. units. The list will be extended later. Units of other branches of the service may or may not exist concurrently with a Coast Artillery unit.

At least one Coast Artillery officer will be assigned to each Coast Artillery unit. He will be supported by the necessary commissioned and enlisted assistants, and if he is the senior army officer present at the institution, he will be designated as the Professor of Military Science and Tactics. It is expected that he will be in every sense a member of the faculty.

A course of instruction has been designed for the Coast Artillery R.O.T.C. student so that there may be no interference with his regular curriculum.

Problems, conforming to standard artillery practice have been prepared for use in conjunction with standard collegiate courses, (such as those in physics, electricity, and mathematics) to make clear the application of the several subjects to Coast Artillery. These problems can be easily used by instructors and classes not familiar with military matters.

The scheme proposed included but one specialized course, that is, gunnery. This will be required during two college years but will occupy but few term hours. However, gunnery itself is but a study of the movement of projectiles and of the theory of errors. It is therefore but a specialized study of certain laws of mechanics in conjunction with the law of probability. A thorough understanding of the latter is so necessary to an understanding of many engineering problems that an engineering student should welcome any instruction in it, supplemental to that which he will normally receive.

Engineering courses in general contain a sufficient course in surveying to meet the needs of the Coast Artillery. If in a particular instance this is not the case, the officer in charge of the Coast Artillery unit will be prepared to teach Orientation to such students as may require it.

The other subjects, which the Chief of Coast Artillery holds as prerequisite to a reserve commission are all of a general cultural character; mathematics, through trigonometry, physics, history, government, English, and the rudiments of one foreign language. Some of these subjects are university entrance requirements and no engineering school would confer a degree upon a candidate less versed in them than the Coast Artillery standard requires.

Two summer camps, each of six weeks duration must be attended by the student. These will be periods of intensive military training. At them, the student will become familiar with the army and its methods, take part in and command military formations, and fire the guns, both artillery and small arms, which he has studied, and which he will man in case of war.

The law provides certain allowances for R.O.T.C. students. In order that he may receive these, the student must pursue studies of a distinctly military value at a prescribed rate, never in excess of five hours per week. The Chief of Coast Artillery realizes that the subjects which he considers essential are by no means the only subjects of distinctly military value and has approved a list of many other subjects of this character.

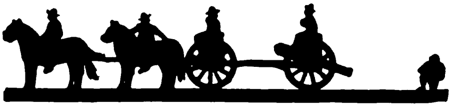
If the student is not pursuing the required subjects at the rate prescribed by law, courses in the additional subjects will meet the time requirement. Doubtless every engineering student will always more than meet the legal time requirement by studies ordinarily taken in the course. It is desired that his studies from the list of optional subjects be as extensive as possible, for each will greatly increase his value to the service. According to the original scheme now subject to modification, drill is not required during the college year. However, physical training is insisted upon. The student must either engage in college athletics or take other exercises to insure his physical development. The Coast Artillery officers at the institution will give every assistance in this matter and will conduct exercises at the request of the faculty, but ordinarily the direction of this work will be under the institution's own physical director.

The first of the summer camps for the Coast Artillery R.O.T.C. will open at Fort Monroe, Virginia, on the twenty-eighth of June and will be attended by students from units already established.

The schedule will be strenous but interesting, and in addition to work, necessarily of a routine character, it will include a number of lectures by specialists in their subjects and visits to points and things of interest to the military student.

The results of the entire movement will be twofold; first, better citizens in peace, available as officers in the event of war; and second, added prestige and strength to the nation.

I would leave with you two thoughts, first that of George Washington who said: "To be prepared for war is one of the most effectual means of preserving peace. A free people ought to be not only armed but disciplined." And second, that of Mazzani, triumvir of Rome, and the spiritual force of the Italian resurrection: "Without national education there exists morally no nation. The national conscience cannot be awakened except by its aid. Without national education common to all citizens, the equality of civic duties and rights is an empty formula."



"Berthas"

By Colonel E. M. Blake, I. G. D.

It has several times occurred to the writer that there has been much confusion and some misinformation concerning the German guns—familiarly known as "Berthas"—that gave Paris, on March 23, 1918, its first bombardment by guns, during the great war.

The pens and imaginations of many newspaper men and other creative literary geniuses ran riot when dealing with this fascinating subject.

Original shooting was done by three guns of 210 mm. caliber emplaced on the northeast slope of the *Mont de Joie* near *Crépy-en-Laonnois.* This hill has a curved crest that makes a natural amphitheatre open to the northeast—a wonderful site for this Gunnery experiment that our enemies sprang on the world.

While there was some surprise, on the date above mentioned, the French High Command had already received information that led them to believe that the Germans had some kind of a surprise ready for the Allies in the spring of 1918. The arrival of these projectiles in Paris was met with coolness and scorn, rather than by the terrified stampede the enemy expected. Undoubtedly he was playing for political effect on the world much more than with any hope that he could lay in ruins enough of the city to make the French sue for peace.

Within a few days after the commencement of this bombardment the position of the guns was accurately located by a combination of the information acquired by sound and flash rangers, terrestrial observers, and aviators; this despite all the enemy's precautions of camouflage, smoke screens, etc., to keep up the mystery of his new engine of destruction at long range.

The French kept records during the fire of these guns as follows: At the front—By all observers who could see or hear from any point, the date, hour, and minute of every round.

In Paris—All policemen near point of fall of a projectile had orders to record date, hour, and minute of explosion, to go at once to the scene and collect all fragments possible, taking them by force, if necessary, from souvenir hunters. All such records and fragments were immediately turned over to the Technical Section of the Artillery. Civil officials of communes in the vicinity of Paris were required to go through the same procedure whenever possible, as to date etc., for projectiles falling outside of the city.

By painstaking study of these records and fragments, the time of flight from *Mont de Joie* to Paris was soon determined to be about 3 minutes. Drawings of a complete projectile, except its ballistic point, were soon reconstucted by Artillery experts, and it was not long before the ballistic experts working with range, time of flight, angle of fall as determined roughly by reference to buildings, were able to calculate possible characteristics of gun, powder, and trajectory to give the observed results.

Captured prisoners, deserters, and spies soon furnished information, little by little, which taken in connection with air photographs and deductions, gave a fair mental picture of this new "Kolossus." In fact one photograph showed that it was about 100 ft. (30 m.) long.

In July, 1918, the capture of a German steel platform, in the *Bois du Chatelet*, 11 kilometers north of *Chateau Thierry*, a circular caisson built up of steel plate box segments bolted together; coupled with about fourteen projectiles, received in Paris from a point near *Fère-en-Tardenois*, (6 kilometers north of *Bois du Chatelet*) at a range of 80 kilometers, allowed a perfectly logical deduction that the gun firing on Paris from the Fère-position was of such nature and dimensions that it could be fired from a platform indentical with the captured one mentioned above.

This deduction was as follows: When the Germans were driven back from *Fère-en-Tardenois* several days after the capture of the *Bois du Chatelet* Platform, an *epi* of identical construction to the *Bois du Chatelet* epi was found, but all the matériel had been withdrawn, leaving only a circular pit of the same dimensions as that occupied by the captured platform. All around this Fère-position were unmistakable evidences of recent occupation—parts of the projectile crates including one practically complete were found and collected. Measurement and close examination soon produced conviction that none other than Paris projectiles were transported in these crates, and, from the length, and a curved collar, surrounding the ogive to steady the projectile in the crate, the radius of curvature of the ballistic cap was determined, —this latter determination having been impossible from fragments.

It had also been deduced from punch marks on fragments, that the projectiles were made to be fired in series, probably to allow for erosion of the gun, necessarily rapid; an interesting confirmation of this idea was in finding the crates numbered—number 10 was nearly complete, and parts of numbers 7 and 13 were identified.

All this led to the conclusion that a "Bertha," at least this particular one, was nothing else but a Krupp Naval 380 mm. re-tubed down to a 220 mm. and firing from the same type platform as the 380, parts of projectiles of this latter caliber having been picked up and identified as fired from the *Bois du Chatelet* platform on the towns of *Meaux* and *Conlommiers.*

To Artillerists it is interesting to know that Paris projectiles were rifled to correspond with the rifling of the gun, thus making rotation certain and independent of copper rotating bands with which we are all familiar. There were two bands of rifling with a slope of 4° on the body of the projectile and a copper obturating band in rear of each.

In its true sense, this arrangement was an example of the Whitworth principle.

In November, 1918, several months after the guns had ceased firing from the *Mont de Joie* position, the writer visited the emplacements with a view to comparing the knowledge of this terrain previously acquired by air photography, etc., with what could be seen on the ground. It was less than two weeks after the Germans had been forced back along this front, and before many souvenir or curiosity hunters could have had time to ply their trade. The accompanying sketch is interesting and instructive. The gun at *a* fired from a concrete platform of which form and dimensions are given, also the arrangement of epi and tracks, which was used by the Germans at all emplaements for heavy guns of which the French have acquired definite information. For one accustomed to machine shops, it is easy to picture a traveling crane with its supports on the outer tracks, and spanning the platform. Once in place, the various steps in mounting or dismounting all matériel, including the crane itself, can be reproduced.

The guns at β and γ fired from some kind of steel platform, probably rectangular, as there remained only a pit in each position about 30 ft. long by 20 wide by 15 deep. The arrangement of tracks was the same as at other emplacements. Probably these steel platforms were forerunner of the idea shown by that captured in the *Bois du Chatelet.* Our enemies had succeeded in removing all trace of platform from β and γ, but evidently no concrete was used in their construction. Captured German prisoners conveyed an impression that one of these "Berthas" had burst, doing much damage and killing a large number of the gun crew, but if this accident did happen the Germans very skilfully removed all evidences of it.

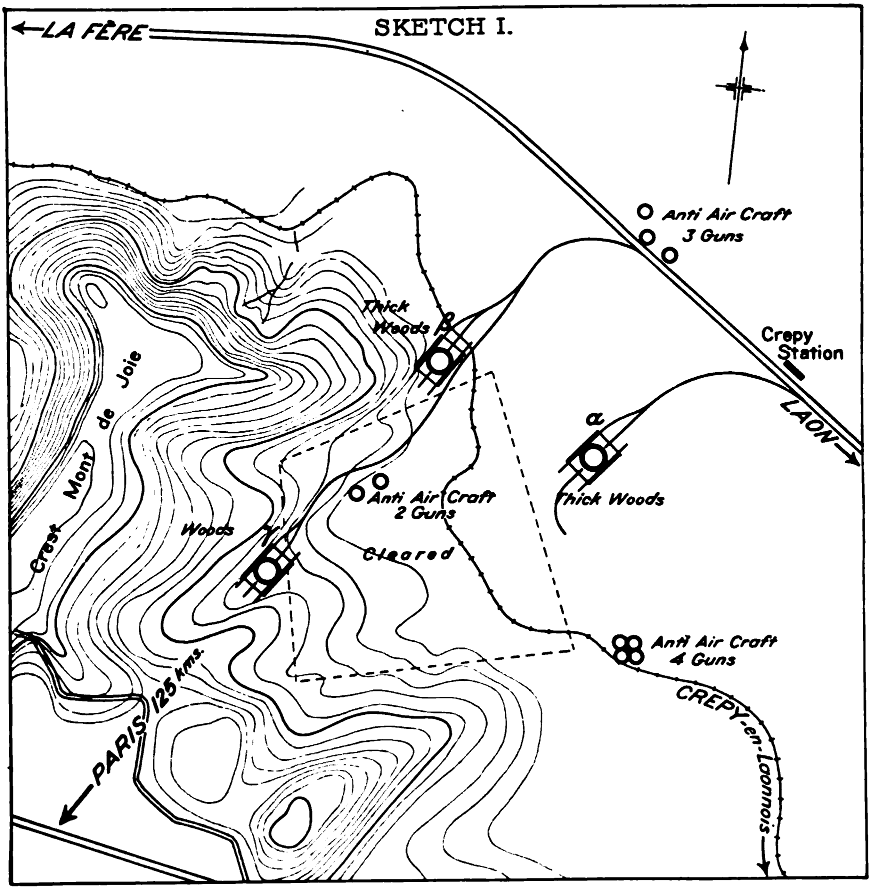


Fig. 1

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SKETCH II.
Details of α

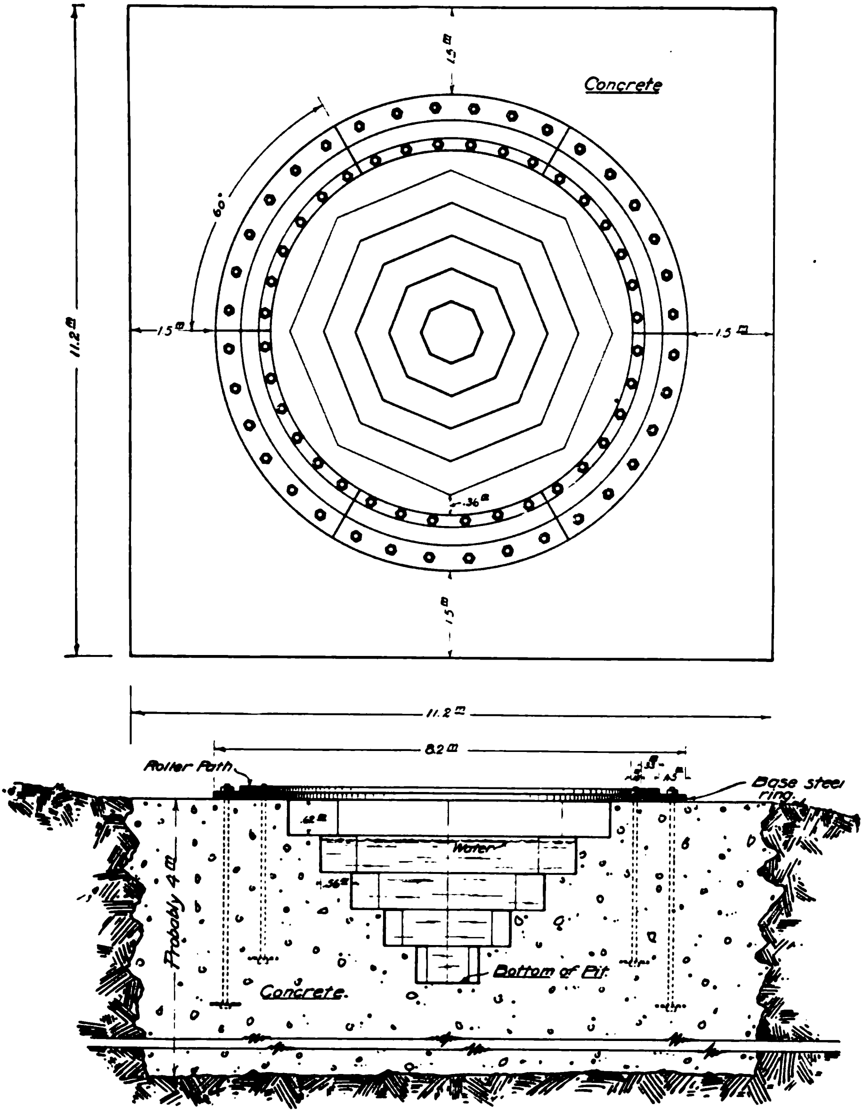

Fig. 2

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Examination of all three emplacements leaves no doubt that the guns were fired at a high angle of elevation, probably above 50 degrees, as neighboring trees show little evidence of blast; whereas, standing on the *Bois du Chatelet* platform, the directions of *Meaux* and *Conlommiers* are plainly marked by the blast.

Ammunition shelters and dugouts for personnel were constructed in the side of the hill at the β and γ positions, they were deep and spacious, but of ordinary type so well known on the front. At the α position, which was level, two concreted shelters with massive concrete tops more than 4 feet thick were place somewhat in rear and on the flanks of the platform.

The camouflage for each position was a large wire net with usual leaf, twig, and grass covering. Its weight was such that a large number of men must have been required to manipulate it. The trees on the lower side of one emplacement had ladder cleats nailed on up to a height of about 30 feet, evidently to be used by the detachment handling the camouflage net, by each man having a cord attached to the edge of the net. The trees around the platform were cut as little as possible and the epi where it crossed a field was covered with earth so that only the top of the rails showed.

It was very interesting to find craters made by 305, 320, and 340 guns in destruction firing and to identify certain craters that were easily seen on the air photographs taken just after firing. These heavy projectiles were fired from the valley of the *Aisne* near *Soissons* at a range of about 30 kilometers. Their detonations must have been very severe on the nerves of the German personnel, as must have been also the harassing and interdiction fire of a French battery of 145 mm. "Schneider Longue" guns emplaced for this purpose just in rear of the French line.

This leads to a short account of the French measures designed to combat the long range guns and protect Paris as far as possible. Briefly, the plan was to harass by the 145's whenever the Paris guns opened, and to fire for destruction whenever conditions were favorable for airplane observation. To protect these batteries from counter-battery and neutralization fire of hostile batteries, it was necessary to emplace enough medium caliber guns to occupy all German batteries in the area and keep their fire down. The success of the plan was marked. The destruction fire by heavy calibers had, I believe, much more moral than material effect. The evidences of the harassing fire were numerous and the personnel must have been kept in dugouts much of the time. This 145 battery was so well protected by the counter-battery neutralization that, although only 2 kilometers in rear of the

French first line trenches, it never lost a man nor had a gun damaged between the time of its emplacement and May 27, and it was effective in minimizing the fire on Paris.

Direct telephone connection was early established between Paris and the Groupment Commander, so that whenever Paris reported a projectile as having arrived, it was only a few minutes before the Germans would receive a violent bombardment in reply.

The last bombardments of Paris from *Mont de Joie* occurred in May, shortly before the great drive of the 27th by which the German line was advanced to the Marne, creating the *Chateau Thierry* "pocket" and rendering possible the emplacement of the "Bertha" that fired from near *Fère-en-Tardenois*, but by this time the Germans seem to have realized the futility of forcing peace by this method as well as the great expense for so little real return. So far as known, this gun only fired fourteen rounds and its removal to the rear was commenced in time to save it from capture in the great allied advance of July 18.

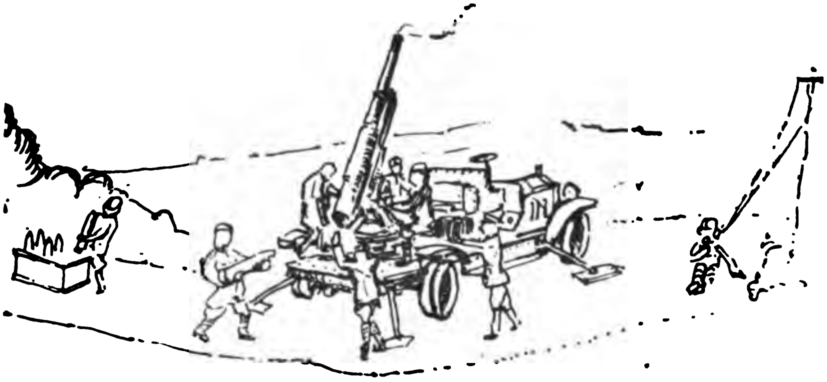
Another "Bertha" of somewhat larger caliber (240 mm.) was emplaced northeast of *Noyon* during the spring of 1918, but its fire had no more material effect than the others.

The moral effect on the inhabitants of Paris was to cause an exodus of the timid into the country south and west of the Capital, and probably between half a million and a million did leave the city for several months, giving a basis for the German reports in the orient that Paris was being depopulated by bombardment. This diminution of population at this time was an actual advantage, as the provisioning of the remainder in the Capital was thereby simplified, and those who scattered into the country were also much more easily subsisted. The laborers in munition factories and other war work stuck to their posts despite "Bertha" and her terrors, and the flow of war matériel was not sensibly diminished.

This "Kolossal" experiment in gunnery has been a subject of some speculation by Artillerists, and its raison d'etre has been sought in various directions. By some it has been attributed to the innate savagery that seemed to delight in making war as barbarous as possible; that spirit that could sink a "Lusitania," bomb a hospital or torture a helpless prisoner! If these reason correctly, our enemies chose a very expensive method of procedure, and not in keeping with the practical business sense they have heretofore shown in their dealings with the world. That they have never been averse to "schrecklichkeit" is only, alas, too well known, but in this case the writer has sought other reasons.

It was generally believed that seven or twelve of these "Berthas" had been placed under construction in 1917 at the Krupp works. Were not the bombardments of Paris in the nature of a test following that of the proving ground? Were they not "gunning for bigger game"?

The intentions of Hindenburg and Ludendorf, as deduced from the spring offensive of 1918, seem to have contemplated driving a wedge between the French and British armies from *Amiens* west to the sea, followed by a mighty effort to annihilate what was left of the weakened British Army and give the Germans Boulogne, Calais, and Dunkirk. As long as the grand fleet under Beatty was holding the sea, they could not hope to land in England, but with Calais and "Bertha" they could land projectiles in London, accomplishing the double purpose of venting their hatred on the arch-enemy and buoying up hope of success, at that time wavering in the Vaterland.



The Technique of Anti-Aircraft Artillery

By Major Glenn P. Anderson, C. A.

The service of an Anti-Aircraft Battery or the knowledge of Anti-Aircraft gunnery required of a Battery Commander differs from ordinary Artillery methods to a greater extent than is realized by the average Coast Artilleryman. Since the Anti-Aircraft has become a part of the Coast Artillery it is the duty of every Coast Artilleryman to give some thought and study to these new methods.

The fundamental elements of seacoast gun fire at a moving target may be said to be (a) Determination of elevation and deflection, (b) Ballistic corrections. The fundamental elements of anti-aircraft artillery fire may be said to be, (a) Altitude, (b) Deflection, (c) Time of burning of fuse, (d) Super Elevation, (e) Ballistic Corrections.

ALTITUDE

The Altitude—the vertical distance of the target above the gun is found by using a horizontal base, two base end stations and projecting the altitude into a vertical plane through the base line. The most modern instrument for finding this element is the "Husson Altimeter."

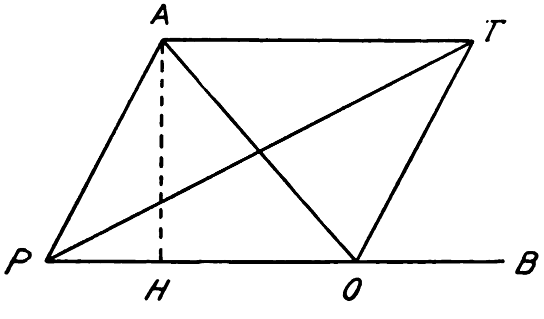


Fig.1

The instruments are so constructed that the angles AOB and APO as shown in Fig. 1 are read at the instruments. If ordinary azimuth instruments were used at P and O the angles TPO and TOP would be read.

P—One station.
O—Second station.
T—Target.
PAO—Vertical plane through base line.
AT—Horizontal line from target perpendicular to plane APO.
AH—Altitude.

From the figure we may see that

$$\cot AOB = -\cot AOH$$

$$\cot AOB = \frac{OH}{AH}$$

$$-\cot AOB = \frac{OH}{AH}$$

$$\cot APH = \frac{PH}{AH}$$

$$\cot APO - \cot AOB = \frac{PH + OH}{AH}$$

$$= \frac{\text{Base}}{\text{Altitude}}$$

$$\text{Altitude} = \frac{\text{Base}}{\cot APO - \cot AOB}$$

In this equation the base is, of course, known and the angles APO and AOB may be measured when desired. This formula is solved mechanically at one station by means of an instrument on which the angle AOB is set automatically when the telescope is pointed at the target. The value of the angle APO is telephoned from the distant station and set by hand. The altitude is then read direct. This instrument is based on the logarithmic application of the formula and is merely a slide rule adding the quantities log Base-log (cot APO − cot AOB) which equals log altitude. It should be noted that since the altitude is read direct from one instrument no time interval system is required. No effort is made to predict the altitude for the future position of the target but this altitude is assumed to be the same as at the present position. This assumption is true in actual practice until after the aeroplane is fired at and it seeks to escape the fire by climbing or diving. The Husson altimeter is very accurate mechanically and permits of no back lash. Other direct altimeters are based on the same principle of projecting the altitude into a vertical plane through the base line but admit of different mechanical solution. The two stations are connected by telephones. At each station two men, an observer and a reader are stationed. In the home station where the altitude is read, a third man is necessary to call or telephone the altitude to the Battery Commander.

Indirect altimeters that use instruments based on the principle of azimuth instruments have been used but no satisfactory design that will stand the rough usage of field service has been invented.

DEFLECTION

In finding the deflection there are two separate and distinct methods-"Linear speed" and "Angular speed" methods. The latter is more accurate but requires special apparatus that is not always available when in the field. The former may be used when no fire control apparatus off the gun is available and the Battery Commander must rely on estimation. In this case the linear speed of the target is estimated from the model and make of the aeroplane. This is quite accurate when the target can be recognized. The following formulae,

$$\text{Lateral deflection} = \frac{Vt \sin \alpha_0}{D \cos S}$$

$$\text{Vertical deflection} = \frac{Vth}{D\,D_0} \cos \frac{x + \alpha_0}{2}$$

may be deduced where

V = Speed of target.

t = Time of flight.

D_0 = True range to present position of target.

D = Range to future position of target.

S = Angle of site.

α_0 = Horizontal projection of angle between line of sight and line drawn through fuselage of target.

α = Same angle at set-forward point.

These formulae are adapted to slide rule instruments placed on the gun, for the operation of which the following is necessary:

Altitude
Fuse Range
Angle of approach
Speed

The determination of a_0 admits of considerable error and this method is made considerably more inaccurate since it required an exact determination of the speed of the wind at the altitude at which the aeroplane is flying. The wind changes the speed of an aeroplane in an absolute ratio.

The angular speed method is best used in conjunction with the Brocq corrector. In this method the angular speed per second, both laterally and vertically, is measured. An instrument called the Double-sight carries two telescopes mounted parallel to each other. They are elevated or moved in azimuth by separate mechanisms but always remain parallel. Each of these telescopes is geared to a crank and by turning these cranks the target may be followed in both vertical and horizontal directions. Geared to the same cranks are magnetoes and electrical currents proportional to the speed of the target are therefore generated. These currents pass through rheostats where resistances proportional to the time of flight may be inserted. The resulting currents shown on voltmeters graduated in mils, are the uncorrected deflections.

Another instrument that solves the deflection problem is the Routin corrector. This instrument embodies the same principles as the Brocq but the operation is mechanical instead of electrical. The instrument also contains apparatus for correcting the deflection and for finding the Fuse Range. Two men are required to operate the Double-sight. The rheostat voltmeters are placed on the gun where they may be set and read by members of the gun crew. The Routin corrector requires five operators and the results are telephoned to the gun. This latter instrument requires two more men and additional telephones as compared to the Brocq system. (The fifth man at the Routin instrument calculates and reads the Fuse Range but in using the Brocq method this man is called the telemeter operator and is an additional member of the gun crew.)

SUPER ELEVATION

The Super elevation, defined as the angle between the line to the future position of the target and the line of elevation of the gun is obtained from an instrument called a telemeter.

This instrument may be placed on the gun and operated by one man. The necessary arguments for operating this instrument are, altitude, vertical deflection, and present angle of site. The reference number obtained from the instrument is called the Fuse Range. This range when set on the range drum of the gun gives the proper super elevation. In graduating the telemeter and range drum, range tables are of course necessary. This table must include, angle of site, angle of elevation, time of flight, fuse range, and altitude. The time of flight which is also the time of burning of the fuse must be determined experimentally. The fuse range in addition to being sent to the gun is also sent to the fuse setter where it is used for the proper fuse setting.

The method of setting the super elevation by means of the range drum is somewhat ingenious. This super elevation is a function of the angle of site and fuse range which it must be remembered varied with the altitude and true distance to the target. By means of a rack and pinion a bar is geared to the gun trunnions. This bar carries a movable pointer which of course moves proportionally to the angle of elevation. This pointer moves across the face of a disk that is also geared to the gun by a different mechanism. When the gun is elevated by this second mechanism the super elevation is set. This disk may then be graduated in fuse ranges and a value that is a function of two variables may therefore be set.

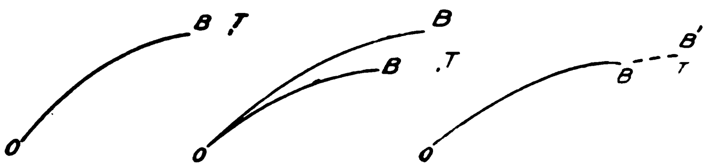


Fig. 2 Fig. 3 Fig. 4

In setting the fuse the instrument used must be fitted with a corrector. If a corrector is not used correction of the time of burning caused by varying atmospheric density must be made by increasing or decreasing the fuse range. This change, at the same time, increases or decreases the super elevation. When a corrector is used the fuse range can remain the same and the time of burning be changed.

Assume, Fig. 2, that a shot bursts at B when it should have burst at T. If this error is corrected by increasing the fuse range Figure 3 shows the results. If this error is corrected by using a corrector and merely changing the length of powder train Figure 4 shows the result.

DEFLECTION CORRECTIONS

In using the angular speed method the deflections found are not correct.

Suppose the target to be travelling from A to B during the time of flight. T T′ represents the vertical travel during the second when the angular travel was measured. Suppose the time of flight to be 20 seconds, then AB will be 20 times T T′,

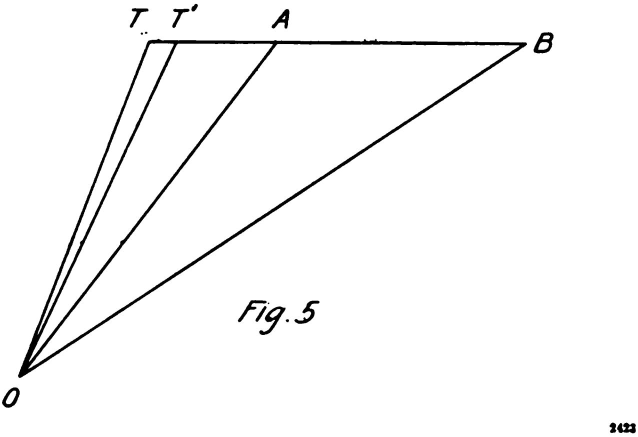


Fig. 5

(T′A is the travel during the time of loading). But if we set the angle AOB as twenty times the angle TOT′ we have a very erroneous deflection. There are various means of correcting for this error, one of the most practicable being the Arnouville Sitogoniotachymeter.

TRIAL SHOTS

Anti-Aircraft fire cannot be corrected by spotting. Suppose the target is at A and we predict that it will be at B at the end of the time of flight.

Suppose that the burst apparently occurred at B′. The only thing that is really known is that the apparent distance BB′ separated the burst and target. Whether the shell went to B′ or whether the target turned slightly and the shell really went to B is never known. In other words there is never a fixed reference point in the air from which the distance to the burst can be measured. As a matter of fact, taking the average case of an aeroplane flying 50 meters per second and a time of flight of 25 seconds it is possible for the aeroplane to go to any point within an egg shaped volume of 5,000,000,000 cubic meters during the time of flight. Since the dangerous volume from a 3-inch High Explosive shell is 5000 cubic meters we might say that the chance of picking the proper point to shoot at is one in one million. Therefore the only course remaining for adjusting anti-aircraft fire is by means of trial shots. If dispersion is small, atmospheric conditions carefully measured and proper corrections made therefore we may hope for some degree of success in hitting.

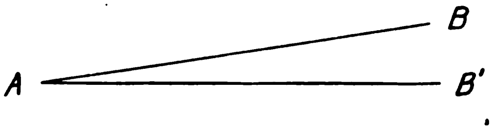


Fig. 6

In firing trial shots the fuse should be set to explode at the summit of the trajectory. The following measurements are taken, Altitude, Time of flight, Vertical and Lateral deflections.

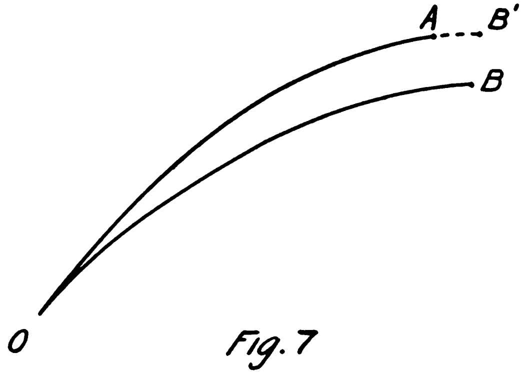


Fig. 7

Suppose that the burst is 15 mils left, 15 mils low, 100 meters low, (Altitude measurement), and the time .4 second less than range table data. The expected trajectory is OA. The actual trajectory is OB. Since we fired at the summit of the trajectory small differences in the time of flight will make very little difference in the altitude.

When we increase the altitude the instruments used are so constucted that the fuse range and therefore the super elevation are automatically increased.

If another shot were then fired the burst should occur at B′. We must then change the corrector on the fuse setter so that we keep the same super elevation but decrease the time of burning, thus moving the burst to A. At the same time a correction is made for the original .4 second error. By firing three to six trial shots and taking the mean thereof very accurate corrections can be obtained. Meteorological data should be obtained at least every three hours and on days when there is great aerial activity trial shots should be fired whenever new data is received. Arbitrary corrections on apparent errors are useless.

This system when carefully applied will give excellent results. It is applicable to Coast defense batteries and all batteries of a semipermanant nature. In the war of movement when changes are too frequent to establish a base line, or communications is interrupted by constant shelling this system falls down. It is then necessary to use the "Linear speed" methods and make arbitrary corrections. Experience is the only teacher for this method. Wireless telephones may solve the matter of communications. A satisfactory self-contained base range or altitude finder may be developed. The methods described in this paper are the latest used in France.

Two features of artillery fire have not been mentioned—Drift and Jump. Very little is known concerning either as regards anti-aircraft fire. In all methods used so far a flat correction has been used for drift, and jump has been neglected.

The study of anti-aircraft artillery brings out every fundamental connected with artillery fire. It requires a study of refinements not ordinarily presented to the student of artillery fire. If the Coast Artillery is to make a success with the Anti-Aircraft Artillery it is encumbent upon all officers to make a study of this subject and to familiarize themselves with the methods used. This new branch is still in its infancy. No more interesting line of work can be presented to the Artillery student. This article merely presents the fundamental problems, each of which should be developed to occupy a large chapter in the Coast Artilleryman's book of knowledge.

The New Ballistics

By Captain Roger Sherman Hoar, C. A.

Editor's Note. This non-technical discussion of the advantages of the new ballistics, now the occasion for an important series of contributions to the JOURNAL, and the nature of the new ballistic tables, is presented for the readers of the JOURNAL in part fulfillment of the promise made in the July issue. In the editorial, *Progress in Ballistics,* in that number, assurance was given that the gist of the significant developments in the science would be presented in the JOURNAL in simple form, stripped of deep mathematical exposition. Here is the beginning. Captain Hoar is one of three Coast Artillery officers especially detailed to the Technical Staff of the Ordnance Department, for the purpose of studying the new ballistics for the Coast Artillery.

Much progress has been made in Ballistics during the Great War. This progress has been due almost entirely to the work of civilian mathematicians and physicists holding temporary commissions or serving in civilian capacity in the Ordnance Department of the United States Army. These men have courteously supplied the JOURNAL with exhaustive technical articles describing their methods and discoveries. It is not the intention of the present article to trench upon the province of these authors, but rather merely to answer the two questions which appear most likely to be raised by the average non-technical Coast Artilleryman with respect to the New Ballistics. These questions are: (1) Just why aren't the old Ingalls Tables good enough? (2) What will the New Ballistics furnish us in their place?

To this end, the present author will give first a brief historical sketch of the development of Ballistics, concluding in a comparison of the old and the new methods; and then an outline of the contents and use of the new ballistic tables.

THE HISTORY OF BALLISTICS

The history of the development of the science of Ballistics may best be understood, if studied in the light of two difficulties with which ballisticians have constantly been confronted. The following theoretical introduction is therefore in point.

If a projectile in flight were subject to no acceleration or retardation, it would continue on forever in a straight line, at muzzle velocity. If subject merely to gravity of uniform intensity and direction, it would describe a parabola. This is the so-called "trajectory in vacuo." But in actual artillery practice, the projectile is subject to both gravity and air resistance, and describes a "trajectory" in the artillery sense.

Little is known as to the exact nature of the gyroscopic wabbling of the axis of the projectile in flight; and ballisticians of all periods have been content to consider this axis as tangent to the trajectory, and (except for an entirely separate tabulation of drift) to consider the trajectory as lying in a vertical plane. The horizontal and the vertical acceleration of a projectile at any point of such a trajectory may be represented by the following equations:

$$\begin{aligned} \text{Horizontal acceleration} &= -R\cos\theta \\ \text{Vertical acceleration} &= -R\sin\theta - g \end{aligned}$$

in which R is the retardation due to the resistance of the atmosphere, θ the inclination of the trajectory to the horizontal, and g the acceleration of gravity. Inasmuch as the air resistance has a retarding effect, and inasmuch as gravity acts downward, the signs are minus. These are the fundamental differential equations of the motion of a projectile. They look very simple, and would be if R could be simply expressed in terms of time, velocity, x, y, or θ. But R appears to follow no mechanical law which can be algebraically expressed. All that we know about R has been derived empirically.

Two great obstacles to the development of Ballistics have always been: (1) lack of knowledge about R, and (2) the difficulty of solving the differential equations. On the basis of the methods pursued in attempting to overcome these obstacles, the progress of Ballistics may be divided into three periods.

The first period, namely all the years prior to about 1865, may be called "the algebraic period." During this period attempts were made to represent R by some simple algebraic expression, and so to solve the equations by the standard methods of calculus. At first it was generally assumed that the motion of a projectile through the air satisfied the conditions laid down by Newton, under which R would vary as v^2. The experiments of Robins and Hutton, and the two sets of firings at Metz furnished the first real data on R. As a result, R was variously supposed to vary as the square or as the cube of v, or as some combination of the two; and, based on these suppositions, there were devised many solutions of the equations, all of which solutions were found in course of time to be insufficiently approximate, and most of which were very operose.

The second period, lasting from about 1865 to the beginning of the present war, may be called "the period of approximations." Practically all of the physics and mathematics of this period were based upon Mayevski's formula:

$$R = A\ v^n/C$$

in which R is the retardation, v the velocity and C the ballistic coefficient. It was assumed that velocities could be divided into four or five intervals (such as 0 to 790 f.s., 790 to 990 f.s., etc.), each interval with its own law of resistance, and each with its own constant value for A and for n. The experiments of this period, notably those of Bashforth and Mayevski, and the Meppen and Gavre firings, were accordingly directed to finding what these intervals were, and what the proper constants would be for each interval. The solutions of the differential equations of motion, notably those of Bashforth, Mayevski, Zaboudski, Hojel, Siacci, Didion, Braccialini and Ingalls, attempted during this period, not only made use of the Mayevski formula, but also, in developing the various equations, used frequent approximations, most of them based upon the assumption of a practically flat trajectory. Thus the equations were finally wrenched into a solvable form. Our familiar Ingalls Tables were produced in this manner.

Let us now consider why these Ingalls Tables, although brought up to date with the latest experimental data, nevertheless fell down during the Great War. The four principal reasons are as follows:

1. Ingalls, like his predecessors, assumed air of a uniform density. This assumption he attempted to correct by introducing an altitude factor, f_a, into the ballistic coefficient, which was supposed to have the effect of giving the air a uniform density, equal to the average density met by the projectile. This factor was chosen so as to produce the correct range, and for that purpose doubtless did represent the proper average, especially in the nearly uniform altitudes of short-range direct fire. But with respect to the other elements of the trajectory, and especially in the case of trajec-

tories passing through many altitudes, f_a did not furnish even a fair approximation. A further disadvantage to the use of f_a was that it provided no solid logical foundation for calculating the corrections for changes in density.

2. Ingalls, following the Siacci method of simplifying the equations, used several approximations which amounted to assuming for the purposes of the simplification, that the trajectory is one straight line throughout. For instance, he substituted $\cos^{n-2} \varphi$ for $\cos^{n-1} \theta$, thus assuming both φ and θ to be practically zero. θ is the inclination of the trajectory to the horizontal at any point, and φ is the inclination at the muzzle of the gun.

Also he assumed that the pseudo-velocity, $\frac{v \cos \theta}{\cos \Phi}$, would have relatively the same dependent functions as the true velocity, v.

3. The use of Mayevski's formula for R, added an approximation to empirical data not very exact in themselves. It is also true that the curve represented by plotting the Mayevski formula has angles at the points where the values of A and n change. This did no particular harm in the Old Ballistics, for corrections for changed atmospheric conditions, stratum by stratum, were impracticable anyhow under the old system. Hence it is not here listed as a drawback to the old system. But it should be here mentioned, as showing why, under the new system, *tabular* values for R must be used in place of a discontinuous *formula;* the reason being that such a formula cannot be given the calculus treatment necessary for the computation of corrections for atmospheric changes.

4. The familiar theory of rigidity of the trajectory was assumed. The errors which this theory introduces, when there is a great difference in elevation between gun and target, are too well known to need repetition here.

By using the foregoing approximations, it became possible to solve the equations of motion in terms of certain auxiliary variables, whose values could easily be obtained by formulas. Ingalls' tabulation of these auxiliary variables is familiar to all. These variables are Z, A, H, log B′, u, T′ and log Q.

These methods were evolved chiefly with regard to data at the point of fall. For the short-range direct fire of those days, they gave fairly precise results for range, time of flight, angle of fall, etc. They gave results not over 10 per cent off for the summit. The rest of the trajectory was shrouded in the mists of the unknown and the unknowable.

Corrections for abnormal atmospheric conditions (i.e. range wind, cross wind, and atmospheric density) have never been more than the merest rough approximations. They "were inaccurate in the extreme and in some cases even gave results of the wrong sign." In addition, the weighting factor curve in general use is now known to bear very little relation to the weighting factor curves precisely computed by the New Ballistics.

The Great War introduced long ranges, high-angle howitzer fire, and anti-aircraft fire. The approximations of the Ingalls Tables, based upon direct fire, at relatively short ranges, with gun and target at nearly the same level, broke down. Precise data were needed at other points of the trajectory than merely the point of fall.

America was not the only country to feel this need. A recent French official publication, in commenting on the pre-war ballistics, says: "Certains recoupments montrèrent bientôt qu'on pouvait commettre ainsi, sous des angles de 30° à 40°, des erreurs atteignant 25 et même 40 pour 100," and adds the hardly necessary comment: "De tels résultats étaient inadmissibles." It is interesting to note that the needs of the War produced simultaneously and independently in England, France, and America, new ballistic methods based upon very similar principles. Thus America is not alone in discarding the Siacci-Ingalls methods.

"In view of the defects which have been enumerated, it may be asked how the methods heretofore in use have sufficed for the requirements of artillery practice * * *. The answer is that the range tables were based on large numbers of experimental firings at various angles of elevation and were largely independent of any mathematical theory. The theory was adjusted to the firings by choosing such a ballistic coefficient at each elevation that the ballistic tables and practice would be in harmony. For a quantity that was treated as constant in the mathematical theory, the ballistic coefficient was made to carry heavy burdens. The ballistic tables became as a matter of fact not much more than interpolation formulas for supplying results in the intervals. * * * Another reason why such mathematically imperfect methods were tolerable in practice is that nearly all artillery firing * * * was at a low elevation where the defects were less serious. And besides this the targets were usually visible from the guns so that the errors in the first shots could easily be corrected." (History of the Ballistics Branch, War Department, Washington, April, 1919).

What was required was a new system, which would give equally precise results for all altitudes of flight and all angles of elevation, and which would furnish dependable information as to all parts of the trajectory.

The first period of Ballistics had been devoted to attempts to construct the trajectory by algebraic methods; the second was devoted to violent approximations, which held good only for very flat trajectories. The third period, namely that beginning with the Great War, ushered in an entirely new method, whereby (1) the differential equations can be solved in their original form to any desired degree of precision, (2) the resistance factor is tabulated, instead of being algebraically approximated, (3) the variation in atmospheric density with altitude is taken into account for each instant of flight, instead of an attempt being made to average it, (4) the elements of the trajectory may be computed with equal ease and accuracy for any point on the trajectory, thus doing away with the necessity for the theory of rigidity, and furnishing data for high-burst ranging, anti-aircraft fire, and fire on balloons, (5) corrections may be properly weighted according to atmospheric conditions at different altitudes, and (6) two new important corrections are introduced, namely for temperature of the air, affecting its elasticity, and for rotation of the earth.

This third period, extending since the beginning of the Great War, may be called "the period of mechanical integration," that being the technical title of the method employed to solve the differential equations of motion during this period.

Up to the beginning of the Great War, every development of Ballistics had been based upon what had gone before. Each new formula was an adaptation or improvement of some previous formula. But the New Ballistics goes back to first principles, and solves the trajectory by numerically integrating the original differential equations of motion, which are as old as the Science of Ballistics. The method of "numerical integration" has been and will be explained in other articles by other authors. Although the derivation and proof of many of the formulas, used in solving trajectories and in computing corrections under the New Ballistics, requires a resort to very high mathematics, yet the use of these formulas requires little more than arithmetic. The teaching of practical Ballistics will therefore be much simpler under the new system than under the old. All that the student of Ballistics will now have to be taught, as to the computation of trajectories, is the formulas for horizontal and vertical acceleration, and the fact that the ballistic coefficient and the resistance function are purely empirical. In other words, that a certain velocity produces a certain resistance factor merely because it does (the factor being tabulated in a G-Table for convenience); and that a certain projectile has a certain C, merely because it has a certain relative ability to penetrate the air (C being ascertained by firings). What a gain in theoretical simplicity!

THE NEW TABLES

In the light of the inaccuracy and inadequacy of the old methods, and the superiority of the new, it is evident that the Ingalls Tables will be of but little further use as a basis for computing range-tables. Pending the publication of the new tables, the Ingalls Tables are still used in the computation of range-tables for small guns, which will not have a very high maximum ordinate or angle of fire, and which will not require the fine modern corrections. Their usefulness in this limited field may still continue. Accordingly either each new range-table must be computed by direct means of express computation of a sheaf of trajectories, or else new ballistic tables must be devised to take the place of the old.

Such tables are already in the course of preparation by the Technical Staff of the Ordnance Department, under the direction of A. A. Bennett, Ph. D., Professor of Mathematics at the Univeristy of Texas (formerly Captain, Ord. Dept.); and Volume I is shortly to appear. Although very bulky, these tables will possess the advantages of uniform precision, of furnishing data with respect to *any* point on the trajectory, and of dealing with the elements of the trajectory direct, instead of through auxiliary functions like those tabulated by Ingalls.

One can enter Volume I with the ballistic coefficient (C), muzzle velocity (V) and angle of departure (φ) as arguments; and take out, for any point on the trajectory, the corresponding remaining-velocity (v), time of flight (t), co-ordinates (x and y) and inclination to the horizontal (θ), in terms of each other. For convenience in the use of the tables, the origin of the co-ordinates is taken at the summit instead of at the muzzle; log C is used instead of C; and the x and y components of the velocity are used instead of velocity and inclination, i.e., the following substitutions are made:

X' for $V \cos \varphi$
Y' for $V \sin \varphi$
x' for $v \cos \theta$
y' for $v \sin \theta$

The result is that we have a tabulation of log C, X′, Y′, x′, y′, x, y, and t. We can enter this volume with any four of these variables and take out any of the rest.

Without going into its principles in this non-technical article, mention should be here made of the "exponential law" of air density. The use of this law permits each trajectory, computed from the summit, to take the place of several trajectories computed from the muzzle, and is one of the achievements of the New Ballistics.

But a table of four-parameters or four independent variables, would be too clumsy. Accordingly Captain Bennett has devised a simplification, comparable to that whereby the Ingalls Tables are made three-parameter instead of four. Ingalls lets X/C equal Z, thereby converting two parameters into one. Bennett uses a Key Table, which one enters with log C, X′ and Y′, and takes out the summit velocity (V_s), and the log of what is called "the summit ballistic coefficient" (log C_s), the product of C by the density factor of atmospheric resistance, the latter being taken at its summit value. Thereby three parameters are converted into two. This Key Table is Table I. Its use is made possible by the "exponential law."

These new ballistic tables are designed to give accurate results even when there is a great difference in level between muzzle and target, as in anti-aircraft or mountain firing. The three-parameter form of these tables is rendered possible only by regarding every portion of each of certain tabulated trajectories as being in itself a possible complete trajectory; and by classifying, under common reference data, all trajectories which can be viewed as portions of one of these tabulated trajectories. The office of the Key Table is thus seen to be to pick out the common trajectory, of which any given trajectory may be considered as forming a part.

This table is divided into a number of sub-tables, each for a different log C; just as the Ingalls Table II is divided into sub-tables, each for a different V. The left-hand pages give log C_s, with X′ and Y′ as arguments. The right-hand pages give V_s, with X′ and Y′ as arguments.

Table II is similarly divided into sub-tables, each for a different y. Each sub-table is a group of four pages, giving x on the first left page, t on the first right; x′ on the second left page, and y′ on the second right; the arguments in each case being log C_s and V_s. It should be noted that x, y, and t are all measured from the summit, not the muzzle. Thus Table II is a triple-entry table, one argument changing by rows, another by columns, and a third by pages.

One enters Table I with the conditions at the muzzle, and takes out the conditions at the summit; then one enters Table II with the conditions at the summit, and takes out the conditions at any point on the trajectory. Of course, this order need not be pursued, in the use of the tables. One can proceed from any four known quantities to any of the four remaining unknown quantities, as in the case of the Ingalls Tables.

Volume II contains all the tables from Table III on. Table III has been designed for use in an emergency, when the speedy construction of a basic range-table is desired, even at the expense of assuming the rigidity of the trajectory, and omitting data for the corrections. It is entered with log C, φ and V; and gives the range and time of flight, both being corrected for assumed average variation of temperature with altitude, and for curvature of the earth.

Table IV is for anti-aircraft fire. One enters this table with log C_s and V_s (both obtained from the Key Table) and with t (measured from the summit), and takes out the co-ordinates of any point on the ascending branch. This table furnishes the first basis for fuse-setting tables.

Table V is for four differential corrections: density, elasticity, range wind, and cross wind. These tables give the effect (on range or deflection, as the case may be) at any point on the descending branch, of a change in atmospheric conditions in any stratum of either branch. Altitudes are, in all cases, measured downward from the summit. The procedure is first to find the sub-table headed with the altitude of the stratum where the change occurs. In this sub-table, find the sub-sub-table headed with the altitude of the point where it is desired to know the effect. Enter this sub-sub-table, with log C_s and V_s as arguments, and take out the effect sought. Table V^1 is a one-stratum correction table for flat fire, and is a simplified modification of Table V.

There are no tables for corrections for changes in initial conditions (C, V, and φ), as these can readily be found by comparing results obtained by entering the main tables with the changed values.

There are tables for the three coefficients which enter into the formulas for correction for the rotation of the earth.

Captain Bennett has also worked out what he calls "critically varying functions." These are linear combinatons of each separate element along the trajectory (x, x′, y′, and t), with coefficients composed of functions of V_s and y, and with C_s occurring as a factor. These possess the advantage of being almost independent of the initial conditions, although varying rapidly along the trajectory; and hence may be tabulated at greater intervals with respect to initial conditions, and still furnish the same degree of precision in interpolating. These functions are comparable with the auxiliary functions tabulated by Ingalls.

Captain Bennett's tabulation of the critically varying functions occupies considerably less space than Table II, and yet can be used to accomplish the same results. Table II, on the other hand, possesses the advantage of greater simplicity of use. If the critically varying functions meet with general favor in practice, it is possible that future editions of ballistic tables, based upon further experimental firings, will omit Table II.

At the end of Volume II are collected various odds and ends of tables, as in the case of Artillery Circular M. These include tables of curvature of the earth, probability, the G-Function of atmospheric resistance, conversion of yards to meters, and conversion of θ and v to x′ and y′.

During the War each range-table has had to be based upon a sheaf of trajectories with differential corrections for each trajectory, the whole being computed expressly for that range-table. This has constituted quite a laborious work. But, with the publication of the new ballistic tables, it will be possible to construct any further range-table by the use of the tabulated data, in much the same way as range-tables have been constructed in the past from the Ingalls Tables.

The new ballistic tables will, however, be limited to a maximum ordinate of 10,000 meters. Above an altitude of about 10,000 meters, a new law of atmospheric density comes into play, also the change in the acceleration of gravity becomes material. For this reason, a three-parameter ballistic table cannot be used for maximum ordinates of over 10,000 meters. Therefore the express computation of trajectories rising above this height will still be necessary.

Thus there will soon be available a set of ballistic tables which will enable range-tables, covering all the modern problems of fire, to be built up with a degree of precision consistent with the demands of modern long ranges and high angles of departure.

The Use of Adjoint Systems in the Problem of Differential Corrections for Trajectories

By Gilbert Ames Bliss

The purpose of this paper is to present a method of computing for a known trajectory corrections of the magnitude of those caused, for example, by the wind. These are called differential corrections because they do not attain values exceeding three per cent of the range, except in unusual circumstances. Among the causes other than the wind which may produce them are slight changes in the initial direction or velocity of the trajectory, variations from normal in the density of the air, variations in the ballistic coefficient, and for long ranges the rotation of the earth. The method described below can doubtless also be used to calculate the drift and other disturbances of the trajectory when the components of the forces which control them are more definitely known.

The methods of the following paragraphs have been found useful in the computation of range tables by the methods of approximation which have been developed during the war, and which have been necessitated by the fact that the fundamental approximation of the classical Siacci theory is not justifiable for high elevations. Taken in conjunction with the schemes for computing a trajectory devised by Major F. R. Moulton and his associates, the results explained here enable one to compute a range table by the newer methods with an amount of labor not excessively greater than that required by the Siacci-Ingalls theory.

In order to describe the essential features of the new method let x, y be the coordinates of the position of the projectile on the original trajectory at a time t, and let $\bar{x} = x + \xi$, $\bar{y} = y + \eta$ be the coordinates of the position which the projectile would have at the same time if the trajectory were disturbed by any or all of the causes mentioned in the first paragraph above. When terms of the second and higher orders in small quantities are neglected, it is found that the variations ξ, η satisfy a system of linear differential equations of the second order, and in terms of these variations the desired correction to the range turns out to be

$$\Delta X = [\xi + \eta \cot \omega]^{t=T},$$

where ω is the positive angle of fall and T the time of flight on the original trajectory. It is possible then to find the range corrections by integrating directly the differential equations for ξ, η and substituting the values so determined in the formula just given for ΔX. With the methods of approximation which apparently must be used, this involves, however, a very considerable amount of labor, because separate integrations must be made for the wind, for the density, and for each other type of correction. The crux of the theory presented in this paper is the replacement of the differential equations of the variations by a new set of linear equations called the system adjoint to the original one. It can be shown then that one approximate integration only of the adjoint system is required, after which the range and deflection corrections are obtainable by elementary arithmetical operations. The only exceptions are the corrections due to the rotation of the earth, for which three definite integrals must be evaluated by Simpson's rule or some equivalent scheme, besides the steps already mentioned.

In Secs. 1-5 below the formulas for the corrections are developed, the fundamental results being the formula (15) for the range corrections due to changed initial conditions, wind, abnormal density or a variation in the ballistic coefficient; the formulas (18) and (19) for the deflection due to the cross wind; and the formulas (22) and (23) for the range correction and deflection due to the rotation of the earth. In Sec. 6 these formulas are rearranged for computation, and suggestions are made for the numerical work. So far as the computer is concerned the results formulated in Sec. 6 form a complete basis upon which the computations can be made without reference to the earlier parts of the paper.

SEC. 1. THE DIFFERENTIAL EQUATIONS OF THE VARIATIONS

It is presupposed that the elements of a trajectory for normal conditions have been computed by a method of approximation. The equations given in this paper are formulated for use with Moulton's scheme for such a computation, but they could be re-adapted to others. The differential equations for the coordinates x, y, z of the projectile on the undisturbed trajectory, as written by Moulton, are

$$
\begin{aligned}
x'' &= -R\,\frac{x'}{v} = -Fx', \\
(1) \qquad y'' &= -R\,\frac{y'}{v} - g = -Fy' - g, \\
z'' &= 0,
\end{aligned}
$$

where R is the retardation due to the resistance of the air,

$$v = \sqrt{x'^2 + y'^2 + z'^2}$$

is the tangential velocity of the projectile, g is the gravitational constant, and F has the form

$$F = G(v)\,\frac{H(y)}{C} = G(v)\,K(y).$$

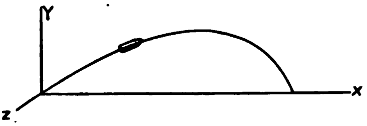


Fig. 1

In this expression vG(v) is the retardation due to air-resistance of a standard projectile moving with velocity v in air at normal sea-level density; C is the ballistic coefficient which enables the formula vG(v)/C to be made to represent the retardation of projectiles other than a standard one under similar conditions; and H(y) is the altitude factor which accounts for the diminution in density of the air, and consequently of the retardation, as the altitude y increases.

A number of expressions have been given for H(y), among which is the well-known Hamilton law of atmospheric density. It is more convenient for computation, however, to use an exponential law of the form $H(y) = e^{-hy}$ where h is a suitably chosen small positive constant. From the standpoint of accuracy it makes no difference which law of density is used, provided only that suitable corrections are applied to allow for the variations from the chosen norm in the densities of the air at the time a particular shot is fired.

On the disturbed trajectory the coordinates and velocity will be represented by the variables

$$\bar{x} = x+\xi,\ \bar{y} = y+\eta,\ \bar{z} = 0+\zeta,\ \bar{v}.$$

The winds at different altitudes are not the same, so that the following and transverse wind components of the wind must be regarded as functions of the altitude y. These will be denoted by $w_x(y)$ and $w_z(y)$, representing the components of the velocity of the wind in the directions of the x- and z-axes, respectively. Similarly the variations of the density from normal at different altitudes may be different and should be regarded as a function of y. To account for them a term $\delta H(y)$ is added to the altitude function.

When a wind is blowing, the motion of the projectile with respect to the air, and therefore also the retardation of the projectile, no longer take place in the tangent to the trajectory. The motion of the air with respect to the projectile is in fact the sum of the motion of the earth as viewed from the projectile and the motion of the air as viewed from the earth. These motions have, respectively, the components

$$-\bar{x}',\ -\bar{y}',\ -\bar{z}'$$
$$w_x(\bar{y}),\ 0,\ w_z(\bar{y})$$

and the retardation therefore takes place in the direction

$$-\bar{x}'+w_x(\bar{y}),\ -\bar{y}',\ -\bar{z}'+w_z(\bar{y})$$

and is determined by the velocity

$$V = \sqrt{[\bar{x}'-w_x(\bar{y})]^2+\bar{y}^{12}+[\bar{z}^1-w_z(\bar{y})]^2}.$$

The differential equations of the motion on the disturbed trajectory may now be written in the form

$$\begin{aligned} \bar{x}'' &= -(F+\Delta F)\,[\bar{x}'-w_x(\bar{y})], \\ (2) \qquad \bar{y}'' &= -(F+\Delta F)\,\bar{y}^1-g, \\ \bar{z}'' &= -(F+\Delta F)\,[\bar{z}'-w_z(\bar{y})], \end{aligned}$$

where

$$F+\Delta F = G(V)\,[K(\bar{y})+\delta K(\bar{y})].$$

In this last expression the term $\delta K(\bar{y})$ is introduced to account for a possible variation in the quotient $H(y)/C$ due either to a variation $\delta H(y)$ from normal in the density of the air, or to a variation δC in the ballistic coefficient, or both. If the equations (1) are subtracted from equations (2), it is found that the variations ξ, η, ζ satisfy the differential equations

$$\begin{aligned} \xi'' &= -F\,[\xi'-w_x(\bar{y})] - [x'+\xi'-w_x(\bar{y})\,]\Delta F, \\ (3)\quad \eta'' &= -F\eta'-(y'+\eta')\Delta F, \\ \zeta'' &= -(F+\Delta F)\,[\zeta'-w_z(\bar{y})\,]. \end{aligned}$$

These equations are true without approximations of any sort. In the next section the linear equations of the variations will be derived from them by neglecting all except first order terms.

SEC. 2 THE LINEAR TERMS IN THE DIFFERENTIAL EQUATIONS OF THE VARIATIONS

Let Δv, ΔG, ΔK, represent the functions defined by the equations

$$\Delta v = V-v = x'\frac{\xi'-w_x(\bar{y})}{v} + y'\frac{\eta'}{v} + \dots.$$

$$(4)\quad \frac{\Delta G}{G} = \frac{G(V)-G(v)}{G(v)} = \frac{G'}{G}\,\Delta v + \dots\dots,$$

$$\frac{\Delta K}{K} = \frac{K(\bar{y})+\delta K(\bar{y})-K(\bar{y})}{K(y)} = -h\,\eta + \frac{\delta K}{K} + \left(\frac{\delta K(\bar{y})-\delta K}{K}\right) + \dots$$

Here primes are used to denote derivatives, and where the arguments of functions are not indicated they are always those of the original trajectory. In the expression for Δv, which results from the expansion of V by Taylor's formula in powers of $[\xi' - w_x(\bar{y})]/v$, η'/v, $[\zeta' - w_z(\bar{y})]/v$, the terms omitted are those of the second and higher orders in these variables. Their coefficients are of the magnitude of x', y', and v. The last two equations are also found with the help of Taylor's formula. The second is self-explanatory, and the terms neglected in the third equation are of higher than the first degree in the product $h\eta$, as is seen by substituting the value $K(y) = e^{-hy}C$. The term $[\delta K(\bar{y}) - \delta K(y)]/K$ is exceedingly small, as will be explained later, and will also be neglected in what follows.

The value of ΔF is now defined by the equation

$$\begin{aligned} \frac{\Delta F}{F} &= \frac{\Delta G}{G} + \frac{\Delta K}{K} + \frac{\Delta G}{G}\,\frac{\Delta K}{K} \\ &= \frac{G'}{vG}\,[x'\,(\xi'-w_x)+y'\eta]-h\eta+\frac{\delta K}{K}+\dots., \end{aligned}$$

and after the omission of the small terms of the second order in the quantities described above, equations (3) give

$$
\begin{aligned}
\xi'' &= -F(\xi'-w_x)-x'F\left\{\frac{G'}{vG}[x'(\xi'-w_x)+y'\eta']-h\eta+\frac{\delta K}{K}\right\},\\
(5)\quad \eta'' &= -F\eta' -y'F\left\{\frac{G'}{vG}[x'(\xi'-w_x)+y'\eta']-h\eta+\frac{\delta K}{K}\right\},\\
\zeta'' &= -F\zeta'+Fw_z.
\end{aligned}
$$

One further approximation, to be justified below, has been made here in replacing $w_x(\bar{y})$ and $w_z(\bar{y})$ by the values $w_x(y)$ and $w_z(y)$. The equations (5) may be regarded as defining the first order effects of the disturbances to the trajectory mentioned in the introduction. They could be integrated directly to determine the variations ξ, η, ζ, but it turns out to be much more convenient to integrate the adjoint system which will presently be described.

It is not easy to discuss the numerical magnitudes of the terms which have been neglected in deducing the equations (5) except in a very rough way on the basis of experience in the computations. In the expression (4) for $\Delta G/G$ the coefficients of the powers of the quotients $(\xi' - w_x)/v$, η'/v, $(\zeta'-w_z)/v$ in terms of which $\Delta G/G$ is expanded are of the magnitude of vG'/G. For the sample value $v=500$ m. the tables give $G'/vG=3/10^6$, and consequently $vG'/G=75/10^2$. The magnitudes of these coefficients are therefore comparable with unity. For a 10 m/s wind the numerators of the quotients all turn out to be less than or equal to 10, so that when $v=500$ the quotients themselves do not exceed $2/10^2$. It is clear then that the magnitudes of the first and second order terms in $\Delta G/G$ are, respectively, comparable with $1/10^2$ and $1/10^4$.

In the formula (4) for $\Delta K/K$ the value of h is .000106, and a liberal maximum for η on the trajectory which the writer has in mind is 100 m. The value of $h\eta$ is therefore less than $1/10^2$, which is also the value of $\Delta K/K$ for a one per cent variation from normal in the density. The first and second order terms in $\Delta G/G$ and $\Delta K/K$, and consequently in $\Delta F/F$, have then the same relative magnitudes, namely, those of $1/10^2$ and $1/10^4$.

In the equations (3) the terms of $\Delta F/F$ are multiplied by quantities of the magnitude of Fx' and Fy', and these do not exceed 100 on the trajectory which is the basis of this estimate. Consequently the first and second order terms in equations (3) have magnitudes comparable with 1 and 1/100, and the latter are the ones which are neglected in forming the equations (5). The replacement of $\delta K(\bar{y})/K$, $w_x(\bar{y})/v$, $w_z(\bar{y})/v$, respectively, by $\delta K(y)/K$, $w_x(y)/v$, $w_z(y)/v$ is justifiable because the numerators of the two sets give density and wind components at $\bar{y}=y+\eta$ and y which are less than 100 meters apart, and in practice the corresponding elements of the two sets will differ by exceedingly small quantities. It has been found in practice that on the trajectories for which computations have been made the corrections for a 10 m/s wind agree with all the accuracy requisite with those found by integrating directly the equations (1) and (2) without approximations of any sort.

For the later developments of the paper the equations (5) may be conveniently written in the form

$$
\begin{aligned}
&\xi' &&= \xi_1 &&+f_1,\\
&\eta' &&= \eta_1 &&+f_2,\\
&\zeta' &&= \zeta_1 &&+f_3,\\
(6)\quad &\xi_1' &&= x'Fh\eta - F\left(1+x'^2\frac{G'}{vG}\right)\xi_1 - x'y'F\frac{G'}{vG}\eta_1 &&+f_4,\\
&\eta_1' &&= y'Fh\eta - x'y'F\frac{G'}{vG}\xi_1 - F\left(1+y'^2\frac{G'}{vG}\right)\eta_1 &&+f_5,\\
&\zeta_1' &&= -F\zeta_1 &&+f_6,
\end{aligned}
$$

where

$$
\begin{aligned}
&f_1 = f_2 = f_3 = 0,\\
&f_4 = F\left(1+x'^2\frac{G'}{vG}\right)w_x - x'F\frac{\delta K}{K},\\
(7)\qquad &f_5 = x'y'\,F\frac{G'}{vG}w_x - y'F\frac{\delta K}{K},\\
&f_6 = Fw_z.
\end{aligned}
$$

SEC. 3. THE ADJOINT SYSTEM OF LINEAR DIFFERENTIAL EQUATIONS

Consider a linear system of the form

$$
\begin{aligned}
&\xi' &&= a_1\xi+b_1\eta+c_1\xi_1+d_1\eta_1+e_1,\\
&\eta' &&= a_2\xi+b_2\eta+c_2\xi_1+d_2\eta_1+e_2,\\
(8)\quad &\xi_1' &&= a_3\xi+b_3\eta+c_3\xi_1+d_3\eta+e_3,\\
&\eta_1' &&= a_4\xi+b_4\eta+c_4\xi_1+d_4\eta+e_4.
\end{aligned}
$$

This system contains only four variables ξ, η, ξ_1, η_1 instead of the six which appear in equations (6), but the principles which underly the construction of the adjoint systems in the two cases are identical. The system adjoint to (8) is by definition

$$
\begin{aligned}
-\lambda' &= a_1\lambda+a_2\mu+a_3\lambda_1+a_4\mu_1,\\
-\mu' &= b_1\lambda+b_2\mu+b_3\lambda_1+b_4\mu_1,\\
(9)\quad -\lambda'_1 &= c_1\lambda+c_2\mu+c_3\lambda_1+c_4\mu_1,\\
-\mu_1' &= d_1\lambda+d_2\mu+d_3\lambda_1+d_4\mu_1,
\end{aligned}
$$

where λ, μ, λ_1, μ_1 are new auxiliary variables, and where the rows of coefficients are the first four columns of coefficients in equations (8).

If the members of equations (8) are multiplied, respectively, by λ, μ, λ_1, μ_1 and added, and if at the same time use is made of equations (9), then it is found very easily that

$$\frac{d}{dt}(\lambda\xi+\mu\eta+\lambda_1\xi'+\mu_1\eta') = \lambda e_1+\mu e_2+\lambda_1 e_3+\mu_1 e_4,$$

so that after integration between the limits 0 and T

$$\Big[\lambda\xi+\mu\eta+\lambda_1\xi^1+\mu_1\eta^1\Big]_0^T = \int_0^T(\lambda e_1+\mu e_2+\lambda_1 e_3+\mu_1 e_4)dt.$$

This relation between the solutions of the two systems (8) and (9) is of fundamental importance for what is to follow. In the case of six variables, as in equations (6), it takes the form

$$(10)\quad \Big[\lambda\xi+\mu\eta+\nu\zeta+\lambda_1\xi'+\mu_1\eta'+\nu_1\zeta\Big]_0^T = \int_0^T[\lambda f_1+\mu f_2+\nu f_3+\lambda_1 f_4+\mu_1 f_5+\nu_1 f_6)\,dt.$$

SEC. 4. APPLICATIONS TO TRAJECTORIES

If the range and time of flight on the original trajectory are designated by X and T, respectively, then on the disturbed trajectory the projectile will have at the time T a position $X+\xi$, η, ζ. The difference in ranges will be very approximately

$$(11)\qquad \Delta X = [\xi+\eta\cot\omega]^{t-T}$$

where ω is the positive angle of fall. This is readily seen from Figure 2, which shows the original trajectory and the projection of the disturbed trajectory on the plane of fire.

According to the definition of the preceding section the system of equations adjoint to the system (6) is

$$
\begin{aligned}
\lambda' &= 0,\\
\mu' &= -hF(x^1\lambda_1+y^1\mu_1),\\
\nu' &= 0,\\
(12)\qquad \lambda'_1 &= -\lambda+F\left(1+x'^2\frac{G'}{vG}\right)\lambda_1+x'y'F\frac{G'}{vG}\mu_1,\\
\mu_1' &= -\mu+x'y'F\frac{G'}{vG}\lambda_1+F\left(1+y'^2\frac{G'}{vG}\right)\mu_1,\\
\nu_1' &= -\nu+F\nu_1.
\end{aligned}
$$

The expression for $-\lambda_1'$ for example, is found by multiplying, respectively, the coefficients of ξ_1 in equations (6) by λ, μ, ν, λ_1, μ_1, ν_1 and adding, and a similar process gives the other second members.

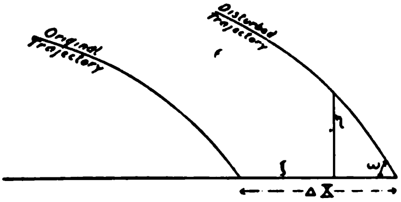


Fig. 2

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To find the range corrections due to the disturbances mentioned in the introduction use is to be made of a system of solutions of these equations with the initial values.

$$(13)\quad (\lambda,\ \mu,\ \nu,\ \lambda_1,\ \mu_1,\ \nu_1)^{t=T} = (1,\ \cot\omega,\ 0,\ 0,\ 0,\ 0).$$

It is easy to show that for this system we have

$$(14)\qquad \lambda \equiv 1,\ \nu \equiv 0,\ \nu_1 \equiv 0.$$

The first two of these relations follow from the fact that λ and ν have derivatives zero and hence remain constant, while the last is true because the function $\nu_1 \equiv 0$ is the only solution of the equation $\nu_1' = F\nu_1$ which vanishes at $t=T$. The formulas (7) and (10) then give

$$
\begin{aligned}
[\xi+\eta\cot\omega]^{t=T} = {} & [\lambda_1\xi'+\mu_1\eta']^{t=o}\\
& +\int_o^T\left\{F\left(1+x^{12}\frac{G'}{vG}\right)\lambda_1+x'y'F\frac{G'}{vG}\mu_1\right\}w_x dt.\\
& +\int_o^T F\left(x'\lambda_1+y'\mu_1\right)\frac{\delta K}{K}dt.
\end{aligned}
$$

In deducing this equation it is to be remembered that the two trajectories have the same initial point so that $\xi = \eta = \zeta = 0$ when $t = 0$. From the formulas (11), (12), and (14) it follows then that

$$(15)\quad \Delta X = [\lambda_1\xi' + \mu_1\eta']^{t=0} + \int_0^T (\lambda_1' + 1)\, w_x\, dt - \frac{1}{h}\int_0^T \mu' \frac{\delta K}{K} dt.$$

This is the first order range correction which was desired.

The deflection due to the disturbances of the trajectory which have been considered above is the value of ζ at the time T. To obtain this value a second system of solutions of the equations (12) may be used with the initial values

$$(16)\quad (\lambda, \mu, \nu, \lambda_1, \mu_1, \nu_1)^{t=T} = (0, 0, 1, 0, 0, 0).$$

For this system

$$(17)\quad \lambda \equiv 0,\ \mu \equiv 0,\ \nu \equiv 1,\ \lambda_1 \equiv 0,\ \mu_1 \equiv 0.$$

since λ, ν are necessarily constants as before, and since the second, fourth, and fifth of equations (12) are now linear and homogeneous in the variables μ, λ_1, μ_1, and hence have only the solution $\mu \equiv \lambda_1 \equiv \mu_1 \equiv 0$ with initial values vanishing at $t = T$. The relations (7) and (10) then give

$$(18)\quad \begin{aligned} \zeta(T) &= [\nu_1\zeta']^{t=0} + \int_0^T \nu_1\zeta^1 F w_s\, dt \\ &= [\nu^1\zeta^1]^{t=0} + \int_0^T (\nu_1' + 1)\, w_s\, dt. \end{aligned}$$

The function ν_1 is expressible in this case in terms of x and its derivatives. For from the first equation (1) it follows that $F = -x''/x'$, and from the last of equations (12), therefore,

$$\nu_1' = -\frac{x''}{x'}\nu_1 - 1.$$

This gives

$$\frac{d}{dt}(x'\nu_1) = -x',$$

and after integration from t to T, since $\nu_1(T) = 0$,

$$-x'\,\nu_1 = -X + x,$$

from which it follows that at every time t

$$(19)\quad \nu_1(t) = \frac{X - x(t)}{x'(t)}.$$

The formulas (15) and (18) are fundamental for the computation, respectively, of the range corrections and the deflection due to alterations in the initial conditions, wind, abnormal density, and variations of the ballistic coefficient. The former shows that the first order range correction is independent of the cross component of the wind, and the second shows that the first order deflection depends only upon that component and the z-component of the alteration to the initial velocity, and not upon the other causes of the disturbances. These are facts which are well known from other sources. In Sec. 6 it will be shown how formulas may conveniently be deduced from these for the computation separately of the different types of corrections.

SEC. 5. DIFFERENTIAL CORRECTIONS DUE TO THE EARTH'S ROTATION

The differential corrections due to the rotation of the earth are deduced here from differential equations for the disturbed trajectory in the form given by Professor W. H. Roever. The equations of the variations which result from them are identical with those which Major F. R. Moulton has established by a different method.

Let Φ be the latitude of the gun position, α the azimuth of the plane of fire measured clockwise from the south, and $\Omega = .0000729$ the angular velocity of the earth's rotation in radians per second. The differential equations of the disturbed trajectory as set down by Roever are then

$$(20)\quad \begin{aligned} \bar{x}'' &= -(F+\Delta F)\bar{x}' \qquad +2\Omega(\bar{y}'\cos\Phi\sin\alpha - \bar{z}'\sin\Phi), \\ \bar{y}'' &= -(F+\Delta F)\bar{y}' - g - 2\Omega\cos\Phi\,(\bar{z}'\cos\alpha + \bar{x}'\sin\alpha), \\ \bar{z}'' &= -(F+\Delta F)\bar{z}' \qquad +2\Omega(\bar{x}'\sin\Phi + \bar{y}'\cos\Phi\cos\alpha). \end{aligned}$$

The axes here are identical with those of Figure 1, and powers of Ω higher than the first have been neglected.

By subtracting equations (1) from the last equations and keeping only first order terms as described in Sec. 2, we obtain the differential equations of the variations correct to first order terms as follows:

$$(21)\quad \begin{aligned} \xi'' &= -F\xi' - x'F\left\{\frac{G'}{vG}(x'\xi'+y'\eta') - h\eta\right\} + 2\Omega y'\cos\Phi\sin\alpha, \\ \eta'' &= -F\eta' - y'F\left\{\frac{G'}{vG}(x'\xi'+y'\eta') - h\eta\right\} - 2\Omega x'\cos\Phi\sin\alpha, \\ \zeta'' &= -F\zeta' \qquad +2\Omega(x'\sin\Phi + y'\cos\Phi\cos\alpha). \end{aligned}$$

In these equations not only terms of higher order in the expression for ΔF have been neglected, as in the preceding pages, but also products of Ω by ξ', η', ζ'. The equations (21) are identical with the equations derived by Moulton. The terms in equations (5) due to wind and abnormal density are missing in equations (21) because the only disturbance now being considered is the rotation of the earth.

The equations (21) can readily be written in the form analagous to (6), the differencc being that the functions f are now

$$\begin{aligned} f_1 &= f_2 = f_3 = 0, \\ f_4 &= 2\Omega\, y' \cos \Phi \sin \alpha, \\ f_5 &= -2\Omega\, x' \cos \Phi \sin \alpha, \\ f_6 &= 2\Omega(x' \sin \Phi + y' \cos \Phi \cos \alpha). \end{aligned}$$

The system adjoint to the equations (21) is identical with the system (12), and the solutions which give the range correction and the deflection are identical with those used in the preceding section having the initial values (13) and (16).

By a process precisely similar to that used in deducing the formula (15) it is found that the range correction due to the rotation of the earth is

$$(22) \quad \Delta X = 2\Omega \cos \Phi \sin \alpha \int_0^T (y' \lambda_1 - x' \mu_1)\, dt.$$

In this expression the functions λ_1 and μ_1 are the same as those appearing in formula (15). Similarly by using the solutions of the adjoint system determined by the initial values (16), the deflection due to the earth's rotation may be shown to have the value

$$(23) \quad \zeta(T) = 2\Omega \sin \Phi \int_0^T \nu_1 x'\, dt + 2\Omega \cos \Phi \cos \alpha \int_0^T \nu_1 y'\, dt.$$

where ν_1 is the function which appeared previously in the correction for the cross wind, given by formula (19).

SEC. 6. SUGGESTIONS FOR COMPUTATION

In this section the essential formulas of the preceding pages are rearranged in a form suited to numerical work. A computer can carry through completely the computation of the corrections to a trajectory on the basis of the results here described, without reference to the earlier parts of the paper, provided that he understands the methods of approximate integration which have been in current use in ballistic work. Of these methods the one devised by Moulton seems the most rapid for the purpose of computing the differential corrections.

In the first place the trajectory itself is supposed to have been found by Moulton's method as a solution of the differential equations

$$x'' = -F x', \quad y'' = -F y' - g. \tag{24}$$

The result of this computation is a table of values of x, y, x′, y′, Fx′, Fy′ at the ends of suitably selected short intervals of time along the trajectory.

The next step is to determine the values of the coefficients of λ_1 and μ_1 in the differential equations

$$\begin{aligned} \mu' &= -x'Fh\,\lambda_1 - y'Fh\,\mu_1, \\ \lambda_1' &= -\lambda + F\left(1 + x'^2 \frac{G'}{vG}\right)\lambda_1 + x'y'F\frac{G'}{vG}\,\mu_1, \\ \mu_1' &= -\mu + x'y'F\frac{G'}{vG}\,\lambda_1 + F\left(1 + y'^2\frac{G'}{vG}\right)\mu_1. \end{aligned} \tag{25}$$

These are the only three of the equations (12) which involve μ, λ_1, μ_1 and they may be integrated separately. Their coefficients can be tabulated, at the ends of the intervals of time mentioned above, from the data already computed for the trajectory itself and from the tables for the function G′/Gv prepared by Moulton. The value usually used hitherto for h is .000106.

For the range corrections a set of solutions (μ, λ_1, μ_1) of the equations (25) is desired with the initial values

$$(\mu, \lambda_1, \mu_1)^{t=T} = (\cot \omega, 0, 0),$$

where ω is the positive angle of fall on the original trajectory. The integration can be carried through by a method similar to the one used for the equations (24), but beginning at the time t = T at the end of the trajectory and worked backward to the time t = 0. The result is a table of values of μ, λ_1, μ_1 at the ends of the time intervals originally selected.

If Θ is the angle between the positive tangent to the trajectory and the x-axis, and if the values of v and Θ at t = 0 are denoted by v_0, Θ_0, the formulas for the computation of the first order range corrections can be written in the form

$$
\begin{aligned}
\Delta X &= [\lambda_1 (0) \cos \Theta_0 + \mu_1(0) \sin \Theta_0]\, \Delta v_0, \\
\Delta X &= v_0[-\lambda_1(0) \sin \Theta_0 + \mu_1(0) \cos \Theta_0]\, \Delta\Theta_0, \\
\text{(26)} \quad \Delta X &= \int_{t_1}^{t_2} (\lambda_1' + 1)\, w_x \, dt = \Big[t + \lambda_1 (t) \Big]_{t_1}^{t_2}, \\
\Delta X &= -\frac{1}{h} \int_{t_1}^{t_2} \mu' \, \frac{\delta K}{K} \, dt = \frac{.01}{h} \Big[\mu(t_1) - \mu(t_2) \Big], \\
\Delta X &= -\frac{1}{h} \int_{0}^{T} \mu' \, \frac{\delta K}{K} \, dt = \frac{.01}{h} \Big[\cot \omega - \mu(0) \Big].
\end{aligned}
$$

The first of these is the correction for a variation Δv_0 in the initial velocity. It is deduced from formula (15) by neglecting the other corrections and setting

$$
\begin{aligned}
\xi' (0)] &= (v_0 + \Delta v_0) \cos \Theta_0 - v_0 \cos \Theta_0 = \Delta v_0 \cos \Theta_0, \\
\eta' (0) &= (v_0 + \Delta v_0) \sin \Theta_0 - v_0 \sin \Theta_0 = \Delta v_0 \sin \Theta_0.
\end{aligned}
$$

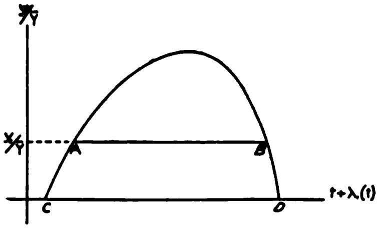

Fig. 3 2428

The second is the correction for a variation $\Delta\Theta_0$ in the elevation, found similarly from formula (15) by substituting

$$
\begin{aligned}
\xi'(0) &= v_0 \cos (\Theta_0 + \Delta\Theta_0) - v_0 \cos \Theta_0 = -v_0 \sin \Theta_0 \, \Delta\Theta_0 + \ldots, \\
\eta'(0) &= v_0 \sin (\Theta_0 + \Delta\Theta_0) - v_0 \sin \Theta_0 = v_0 \cos \Theta_0 \, \Delta\Theta_0 + \ldots.
\end{aligned}
$$

and neglecting terms of higher order in $\Delta\Theta_0$. For a 1m/s following wind blowing between the times t_1 and t_2 the value of w_x is unity between t_1 and t_2 and zero elsewhere. Hence formula (15) gives the third formula above for the range correction for such a wind. The fourth formula is similarly the correction for a one per cent variation from normal in the density of the air strata passed through between the times t_1 and t_2, since for such a variation $\delta K/K = \delta H/H = .01$ between t_1 and t_2 and is zero elsewhere. Finally the last formula gives the range correction for a one per cent change in the ballistic coefficient for which $\delta K/K$ is approximately $-\delta C/C = -.01$. The values of all these corrections are completely determined when the elevation θ_0, the values of Δv_0 and $\Delta\theta_0$, and the table of values of the functions μ, λ_1, μ_1 are known.

To obtain a wind weighting factor curve in a convenient form, the function $t+\lambda_1(t)$ may be plotted against the quotients $y(t)/Y$, where Y is the maximum ordinate of the trajectory. On the resulting curve, shown in Figure 3, the third formula (26) shows that the length of the line $\overline{AB}$ is the range change caused by a 1 m/s wind blowing only above the altitude y_1, while $\overline{CD}$ is the range change due to a 1 m/s wind blowing throughout the entire flight of the projectile. If the quotients AB/CD are plotted against y/Y, as in Figure 4, then the line $\overline{EF}$ is the fraction of the total range change $\overline{CD}$ caused by a 1 m/s wind blowing only below the altitude y_1, and the difference $\overline{GH}-\overline{EF}$ is the fraction of the total range change $\overline{CD}$ caused by the same wind blowing only in the zone between the altitudes y_1 and y_2. Hence if the velocities w_1, . . . , w_n of the following components of the wind in a sequence of n zones are known, the total range change produced by them will be approximately

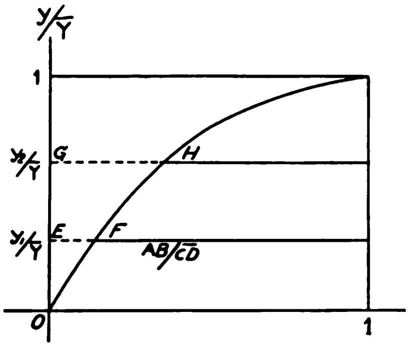

Fig. 4

$$\Delta X = (p_1w_1 + \ . \ . \ . + p_nw_n)\ \overline{CD},$$

where p_1, . . ., p_n are the fractional weighting factors determined for the different zones as differences $\overline{GH}-\overline{EF}$ from Figure 4.

In an entirely similar manner a weighting factor curve for density may be constructed. The differences are that the curve in Figure 3 should for this case be the graph of $\mu(t)$ against $y(t)/Y$, and the total range change for a one per cent variation from normal in density throughout the entire flight of the projectile is $-.01\ CD/h$.

The formulas (18) and (19) give the value

$$\zeta(T) = \int_{t_1}^{t_2} (\nu_1'+1)\, w_z\, dt = \Big[t + \nu_1(t)\Big]_{t_1}^{t_2}$$

with

$$\nu_1(t) = \frac{X-x(t),}{x'(t)},$$

for the deflection due to a 1 m/s cross wind blowing only between the times t_1 and t_2. This is identical with the formulas which have been used in other theories. On the basis of it weighting factor curves for cross winds can be constructed as above for following winds and density variations. When the value of ν_1 from equation (19) is substituted. the first term of formula (18) is the deflection

$$\zeta(T) = X\frac{\zeta'}{x'} = X \tan \Delta\alpha$$

corresponding to a slight change $\Delta\alpha$ in the azimuth of the plane of fire.

Finally the formulas for the first order range correction and deflection due to the earth's rotation are

$$\Delta X = 2\Omega \cos \Phi \sin\alpha \int_0^T (y'\lambda_1 - x'\mu_1)dt,$$

$$\zeta(T) = 2\Omega \sin \Phi \int_0^T (X-x)\, dt$$

$$+\, 2\Omega \cos \Phi \cos \alpha \int_0^T (X-x) \frac{y'}{x'} dt,$$

where Φ is the latitude of the gun position and α the azimuth of the plane of fire measured clockwise from the south.

These are the same as the formulas (22) and (23) of the preceding section except that the value of ν_1 has now been substituted from formula (19). The three integrals which appear in these formulas must be evaluated by Simpson's rule or some other equivalent method.

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EDITORIAL REVIEWS

RECOGNITION FOR THE ARMY

The lament is sometimes heard that the Army lacks *recognition*—of its worth, of its problems, of its full prestige. Before joining the lament, it is well to realize that the whole question of *recognition* may very well hinge on the idea of what recognition means. From the viewpoint of an officer to whom recognition means only a swelling hymn of praise from citizens and statesmen, for the grand and glorious Army they are privileged to maintain, naturally a surging flood of critical comment from the press and a rising tide of disparaging investigation do not constitute *recognition*. In a very real sense, however, even criticism is a form of recognition. measurable by the earnestness and extent of the criticism. In the days before the war, one of the things from which the Army suffered was a lack of interest and intelligent appreciation on the part of the American public.

Now the war brought the Army and the people together. By the tremendous processes of building the huge force needed for the war, the Army, while giving distinctive color to the spirit of the new levies, was itself swept, like a sudden gale through a dusty garret, with a refreshing flood of new ideas, to supplement and sometimes to supplant its old traditions. The close of the war finds us in a position where scarce a family throughout the broad land fails to number a wartime soldier among its relationships. Thousands upon thousands of families count the loss of husband, son, brother, or cousin. Naturally there is a quickened interest through the land, questioning: first, whether those who died, died not in vain, and second, whether their Army, our Army, is in all ways the Army to fulfill American needs.

Just now opinion and interest anent the Army are available for the Army's use. Some of this opinion will flow anyhow, and part will not flow unless the reservoir is tapped. There is to be found much praise and appreciation, and also much criticism. Either kind of notice is valuable only as it springs from a source, impartial, analytical, informed, and unimpassioned. Of this sort is the letter of the Hon. Herbert

Parsons to Senator Wadsworth, originally published in the July issue of *National Service,* and with the permission of that magazine, reprinted under *Professional Notes* in this issue of the *Journal.* All of the specific recommendations contained therein are worthy of the sincere cogitation of the professional officer, and whether agreed with or not are valuable additions to the thought in their respective fields because they represent the reaction of a keen mind, concentrated freshly on the military field, helping us to see our own problems with a perspective that our own positions make it hard to gain.

The very tide of criticism now flowing in the land is an omen of opportunity for the service. If it be not seized upon and used, the service will earn the reproach of the years to come in its failure to grasp the advantage of an awakened public interest which the Army has not had before, and if relinquished now, may not be regained.

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PROMOTION

Among the subjects covered in the letter of the Honorable Herbert Parsons, one which is most important as well as most delicate from the standpoint of the regular, is the question of promotion.

For long years promotion has been the subject of controversial agitation among officers, in the service newspapers, and in certain of the service journals. Yea, verily, promotion has been the source of frequent and unfortunate friction and bickering between the arms of the Service.

The JOURNAL has not been unaware of the importance of this subject and has not been oblivious to its various aspects. However, in bringing to the fore for the discussion of the Corps seemingly timely and important questions, the JOURNAL has not hitherto advanced a discussion on promotion, primarily because of a desire to avoid the possibility of controversy between the Coast Artillery and other branches of the Service. Nevertheless, tides of opinion like the tides of the sea are irresistible in their advance, and the question of promotion is now forging to the front with the proportions of an issue which must be faced and cannot honestly be dodged. This letter of Mr. Parsons and other public utterances of prominent citizens have lighted the whole promotion question with new color. The emphasis has changed. Hitherto, promotion has been looked on, both within the Service and to a great extent without, as a vested right of each officer, a right not to be alienated in individual cases except by misconduct on the part of the officer. Too much emphasis has been laid on the interests and the advantage or prejudice of the individual officer. In whatever promotion scheme is under consideration, arguments for the advantage of the system have been staked on increased efficiency through the allaying of friction, the removal of bickering between the Services, the increase of co-operation, and the creation of contentment on the part of the individual officer. The JOURNAL heartily agrees with the *United States Infantry Association* that the elimination of promotion as the principal or moving cause for legislation, is imperative. But the JOURNAL does not believe that the creation of the single list can alone be the complete answer to the promotion question. The fundamental idea and argument of the single list stands solidly on the conception of guaranteeing, as between all officers in every arm, a continuing equity of the self-interest of the individual officer. In other words, the mainspring of the single list idea is selfish and not social. The emphasis in arguments for the single list is not laid on a contention that the single list insures the means for developing personal initiative, alertness, executive skill, and the qualities of dominating personality. It has often been said and is really appreciated that an Army must be a *team* and have the highest quality of *teamwork*. Now the only defensible object in having a *Captain* for any *team* is to insure teamwork, that is the co-ordination and exploitation of every element of spiritual, mental, and physical resource latent in each man of the team. To pursue the analogy,—among college men is traditionally known the disastrous effect on the fortunes of a certain university in football of a policy, where for a period of years the leadership of the teams was awarded in accordance with the mandates of social consideration rather than by the criterion of football generalship.

A Single List—perhaps. It is not the intent of the present discussion to consider the arguments for or against a single list. It is believed that in the phase of the promotion problem which it is desired to discuss here the incorporation or exclusion of the single list idea would not affect what the JOURNAL believes to be a deeper significance in the whole problem. And it seems necessary to assert the existence of this deeper and more fundamental consideration in the problem. Real efficiency in the Army requires not only a body of officers who are imbued with contentment, but as well with earnestness, initiative, and ability, and furthermore, some system which will develop and sustain these qualities always predominant.

Mr. Parsons is temperate where other writers are violent in recognition that during the War the leadership of the Regular Army suffered through the fact that the conception of the vested personal rights of an officer to retention and promotion had dominated the conception that every individual consideration must bend to the good of the Service. The fact of the existence of some dead wood among the higher grades of the Regular Army during the War is known to have existed. Mr. Parsons states the case very mildly. Governor Allen of Kansas in his article in the July *North American Review* emphasizes the condition with more heat and consequently with less justice.

Ever since 1890 the Army has had within its grasp the means of eliminating at least the palpably unfit by examination at the time of promotion. The Army has been diffident in wielding this instrument for its purification. As a result the Army is paying the penalty of popular mistrust through the weak performance of misrepresentative officers who were still hanging on in the Service when the war came. In one sense this condition is neither here nor there. We are looking forward and not rehashing the past. The only point in this reference is that experience demonstrates that worthless officers will not be eliminated by their fellow officers under a system so little imperatively rigid as the system we have had.

But public thought is awakened and public attention is now focussed on the Army, its officers, and its promotion system. A public demand for promotion reform is reflected in the bill for the reorganization of the Army sent to Congress by the Secretary of War. Whether particular officers relish the idea of change or not, the fact must be faced that the people of America, having awakened to the results of a system of promotion the like of which is not tolerated in any official or business enterprise commanding the services of a necessarily high grade of men, will no longer tolerate the system we have lived under for so many years. Willy-nilly, promotion through selection and elimination is coming. Affairs have progressed to the point where it is a question whether the Army is to lead the procession in reconstructing its own affairs, consciously and positively molding details in the prescription of popular purpose to the attainment of a sane workable system, or whether the Army is to lag behind to be dragged into line as by a halter. Consequently it is high time that serious thought be given to this situation by the JOURNAL and by every Coast Artillery Officer.

Unquestionably a great many officers are opposed to the idea of selection and elimination not because they do not approve the theoretical principle but because for one reason or another they distrust its operation in practice. In attempting an impersonal consideration of a question of this sort it is necessary and also hard to separate a concern for the effect of the proposition on the Army as a whole from its possible effect on one's self. Therefore, when the individual officer faces the necessity for forming his conclusions on the problem of promotion it is first of all necessary that he search honestly within himself to decide whether a doubt as to the practicability of selection and elimination arises from an uncertainty as to the probable effect on the Army or as to the probable effect on his own fortunes.

To justify the establishment in practice of an admittedly desirable theory it is necessary that certain definite criteria should be established, assented to, and fulfilled in the system to be adopted. Some of these essential criteria seem to be the following:

(1) The bases of military excellence—the standards of comparison—must be crystallized and must give due credit for faithful routine work in positions where no opportunity is presented for brilliancy in achievement. In particular must the tendency be avoided of giving too much credit to the officer whose abilities are more distinctly those of the scholar, the bookworm, or the author.

(2) An important quality of personal effectiveness must be recognized and proper means made available to determine it. This is the quality of a willingness to accept responsibility. The day of "passing the buck" is past, and the "buck passer" must be branded and condemmed.

(3) A transcendent element of fitness in an officer must be conceded in the ability to lead and inspire men and to maintain discipline without arousing the personal hostility of his subordinates.

(4) The system must be able to recognize and give ample credit for the quality of common sense.

(5) In the choosing between officers of apparently equal attainments and merits it should be recognized that the officer with the greater experience should be the more valuable; consequently that in all cases of reasonable doubt seniority should rule.

(6) No officer should ever be allowed to skip a grade, and in time of peace, no officer should be promoted from any grade until he shall have served in it a definitely minimum period of time.

(7) An officer's selection for promotion should be based on a continous series of reports. In every report on an officer by a superior his relative excellence with all other officers of the same grade serving under the reporting officer should be stated. By this means in a series of reports any one report which represents personal animus on the part of a reporting officer will be detected.

(8) Selection should not be operative with regard to any officer until he has been in the service long enough to "find himself" and establish a personal reputation. Hence in the general case promotion from the lowest grade to the next in any arm, properly should be by seniority.

(9) In any selection scheme the final act of comparison, compilation, or selection, as you please, will undoubtedly have to be made by a board of officers. In general it is believed that a more correct analysis of individuals in lower grades will be made by officers who are not too remote in experience and viewpoint from the officers under consideration for promotion. Consequently it is believed that selection boards should include officers of as many as possible of the grades superior to the grade from which selections are to be made, with, indeed, a particularly strong representation in the next senior grade.

(10) If possible to avoid it, no officer should ever serve on more than one selection board.

(11) Any promotion system which includes selection should by all means also include elimination, and a scheme of graded retirement. The details of operation to secure this elimination deserve the most painstaking consideration. It may or may not be that the scheme proposed in the War Department's reorganization bill is the best for the purpose. A principle which should be followed is to insure as far as humanly possible that each individual case of elimination

shall occur as the result of the cumulative operation of the law, and not be dependent upon the direct action of a board.

(12) Most important of all, recognition must be yielded to the requirement that the desired promotion system shall provide, first, for the good of the service, and second for the benefit of the individual.

Having accepted a set of standards to which a system of promotion by selection must conform in order to be satisfactory it still remains to be assured that the apparently grave objections to selection can be obviated. The first objection which is heard against promotion by selection is the alleged difficulty of attaining a square deal in its operation. There are those who feel that political influence will count for more than solid ability and that officers will find it necessary to "bootlick" the favor of their superiors instead of being content to earn their respect. It would seem that this latter objection is a sorry commentary on the opinion prevailing as to the way the favorable judgment of an Army officer is to be earned. The quite general doubt as to the ability of the Army to keep free from the taint of external influence with a system of selection deserves particular comment. It should be remembered that military boards have long been used for various purposes, in many cases to settle matters in which private persons had large pecuniary interests involved. Nevertheless the record is clean from any aspersions that boards of officers have been perverted in their actions from the course dictated by their experience and conscience. Politicians realize and always have, that a military board is a dangerous thing to tamper with and the attempt has not been made in our history.

Again it is worth considering that we already have a great deal of selection in the Army and the public service which is not subject to political influence. For instance: the graduates of West Point are assigned a standing among themselves by a process of selection which is in the hands of the Army and with which politicians never attempt to interfere. If such influence were to be looked for, this is a place where it should be expected, for the standing assigned to a graduate controls, to a large extent, his advancement throughout his military career. We have another and very shining example of the operation of selection without political interference in the Civil Service of the United States. Indeed, it is recognized that politicians resist the inclusion of classes of public servants in the Civil Service for the very reason that they feel that as soon as any such class has entered the doors of the Civil Service it is beyond the reach of their political jobbery.

There is also felt a serious doubt of the ability to discriminate between different officers in accordance with their actual merits. Officers are stationed far apart, on widely differing kinds of duty and under different commanding officers and the opinion is frequently heard that an officer who "serves near the throne" will have a better opportunity for promotion than an officer at a remote station and in an inconspicuous situation. It is believed that the recommendation to have boards of officers composed of representatives from all the grades senior to the grade from which selection is to be made, coupled with a reference only to reports conforming to the principle of comparison above suggested, would satisfactorily solve this difficulty.

It is believed that a fundamental element of success in the operation of any scheme of selection will be the inclusion of some form of elimination. The pushing ahead of certain officers means that the other officers passed over are going to be reacted upon in either one of two ways. The officer who has been passed over may take heedful counsel with himself, spurring his own efforts to the end that he may not again be passed over. On the other hand, instead of being stimulated by the fact of being passed over in selection, certain officers of naturally indolent nature may be overcome with discouragement and disgust. A proper regard for the caliber of Army officer material precludes the notion that there could be any considerable number in this latter class. However, such number as there might be would constitute a source of disaffection and moral poison in the corps of officers. While the acceptance of the necessity for elimination is necessary to the successful operation of the new system in promotion, yet this one phase of the whole problem is the most delicate of all, and it is not to be supposed that any solution attempted can be expected to prove instantly successful. Indeed, after a charting of any new field of progress the formulae are necessarily empirical, and the successful prescriptions will be only those which have been proven in practice and their details modified by observation of their results in operation.

Once more and always, let this emphasis come to the fore; that the new system is not designed for the purpose of giving personal reward to the individual officer who is to be determined as the most deserving of reward, but instead is to improve the standard of the officers in all the higher grades and positions of responsibility. Stating the case in another way, the system can still be a success and yet not be able to seize upon the most meritorious and distinguished officers for promotion on the occasion of each selection for the purpose. So long as the system can be made continually to keep sifting the better men toward the top, and dropping the poorer men behind, and so long as it can prevent an absolutely inferior man ever from passing his betters, the system will have achieved its purpose.

The conception of a system of selection should be broad enough to include the purpose and the facility for putting the right man on the right job. Considered from this standpoint, the incorporation of the Single List idea in a scheme of selective promotion might facilitate this purpose of fitting officers into situations for which they develop a special fitness in the course of their service. As has been noted in a recent contribution to the *Army and Navy Register* on the subject of Selection, we do recognize and always have recognized the necessity of selection in choosing officers and men to fulfill specific duties. As this article says:

> "How do we get adjutants, recruiting officers, quartermasters, stenographers, cooks, military attaches, superintendents of military academies, chiefs of staff, orderlies? By selection. Can anybody conceive of an army run by a roster, and does anybody lay down on his job because the pleasant and disagreeable details of the service are not filled by seniority? In all military history is there a single instance of anything, great or small, having been accomplished except by a man who was selected to do it or by one who himself sprang out in front of the mob and led it?"

Nearly every leading nation but ourselves has selection in some form, either with or without connection with promotion by seniority. We hardly can be justified in assuming that the reasons which have warranted all other leading nations to adopt in somewhat varied fashion, provisions for selection, are wholly without weight in our case.

In our own country selection is in operation in a sister service, the Navy. Careful inquiry has brought out the fact that after actual trial of selection in the Navy, the objections that are being made are not against the principle of promotion by selection but amount to criticisms in details of operation; details which as experience dictates, may be changed to better the practical operation of the system.

This whole question is one of the most important subjects confronting Coast Artillery officers for consideration, and as has been said, it cannot be dodged. In facing the issue the

Journal desires only to be of assistance to the Corps, and to this end will welcome the opportunity to receive and disseminate the comment and opinion of the officers of the Corps.

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THE NEW COVER

It has been observed that periodicals commonly follow a feminine fashion in talking about their change of dress. The Journal thought to appear in new clothes without self-conscious remark. But remark has been forthcoming from Journal readers. In the comment which has reached the editorial sanctum, the weight of opinion is clearly on the side of satisfaction with the change. Approval is not unanimous, as was to have been expected. Inasmuch as Journal readers have opened up a discussion on our new clothes, a statement of the reasons for the change is properly forthcoming.

First of all, financial policy dictated a change. The cover which disappeared with the June issue was of stock which was unwarrantably expensive, and the design called for four printing operations. The new cover stock is reasonably economical, and the design purposely complies with a requirement for one printing operation. The dominating idea is that readers of the Journal should get full value by putting the cost *inside* the cover instead of *on* the cover. The Journal is prepared to strain its resources for expense in the effort to increase the usefulness and attractiveness of its contents. To cite an instance, the illustrations for one article alone—"Coast Defenses Constructed by the Germans on the Belgian Coast,"—concluded in the August issue, represent an expense item of $198.78.

Having deemed a change of cover a desirable policy, the adoption of the new cover was a logical tribute to the traditions of the JOURNAL OF THE U. S. ARTILLERY. This, one of the deans of professional military journalism, was, from its beginning in 1892, clothed in artillery red until the dislocation of the dye industry caused by the European War, necessitated, in 1916, a change to another color of paper. Now that America is independent of German dyes as of the German menace, the return to artillery red is a symbol of victory as well as a recognition of the Journal's traditions. The design aims to be simple, balanced, and straight-forward, in keeping with the like standard of its contents, by which the Journal intends to command the respect and support of all the Coast Artillery, both active and reserve.

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THE PRIZE ESSAY COMPETITION

The JOURNAL has been emphasizing in numerous editorials the importance to the Coast Artillery for the crystallization in writing of the achievements in the Coast Defenses, so that through the JOURNAL, the whole Corps may benefit therefrom. A further suggestion which ties in the general good with individual interest arises in a reminder of the JOURNAL'S annual Prize Essay Competition. If your ideas command your own respect and are backed up by your conviction, they well deserve to be embodied in careful diction and be matched in the arena for the prizes of One Hundred and Fifty and One Hundred Dollars, which in these days of mounting costs and dwindling savings are stakes doubtless worth playing for.

Would that the JOURNAL could recompense every good contribution with a check for One Hundred and Fifty Dollars! Unhappily it cannot, but your work has as good a chance as anybody's for one such check.

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THE LIBRARY, COAST ARTILLERY SCHOOL

Under the present organization of the Coast Artillery Training Center at Fort Monroe, the Library, Coast Artillery School, along with the JOURNAL, LIAISON, and the Printery and Bindery, is under the Information Section of the Staff—G2, if you please.

It is the business of this Library to supply up-to-date information and data on any subject related to the professional effort of the Coast Artillery Corps. This does not mean alone that small slice of the Coast Artillery Corps stationed at Fort Monroe. Under its necessary rules regarding care and return of books, the Library will forward to a Coast Artillery officer, stationed wherever he may be, for his official use, any book in the Library excepting a certain class of reference works, such as dictionaries and encyclopedias.

If ever sufficient Library personnel becomes available to make possible the effort, selected lists of works on various important subjects will be published in the JOURNAL, and LIAISON.

In addition to this service, the Library is able, by reason of its relations with the Library of Congress and certain other libraries, to obtain references and complete bibliographies on practically any subject that a Coast Artillery officer may desire. The Library of the Coast Artillery School is here to serve all the Coast Artillery. If the Library has not what you need, it will get it.

Related to this question, although unrelated to the Library, is the reminder that the Book Department of the JOURNAL is prepared to obtain for you any book published anywhere, that you may want to buy.

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ORIGIN OF FREE BALLOON PLOTTING BOARD

The attention of the JOURNAL has been called to Appendix 1 of Lieutenant Tannehill's article on the "Pilot Balloon Method of Determining the Direction and Speed of the Upper Winds," in the July issue of the JOURNAL. The Appendix referred to gave a description of a Free Balloon Plotting Board, with the statement that the description was obtained from data furnished by Lieutenant Colonel T. O. Humphreys, C. A. The editors of the JOURNAL were well aware that Lieutenant Colonel Humphreys had obtained this data at the Aberdeen Proving Ground, and that he laid no claim to having originated the Board. Credit for the development of this Board should be given to the Signal Corps Detachment at the Aberdeen Proving Ground. It is regretted that any possibility was given by the JOURNAL for misunderstanding as to the origination of this Board.

PROFESSIONAL NOTES

Notes on Army Reform Made at the Front

Reprinted from *National Service*, by permission of the Editor

The following letter from Hon. Herbert Parsons (late Lieutenant-Colonel, General Staff, Assistant Chief of Staff G-2, Fifth Division A. E. F.) to the Hon. James W. Wadsworth, Jr., senior U. S. Senator from New York (now Chairman of the Committee on Military Affairs of the Senate) is deemed of such general interest and value that permission has been obtained to publish it in full.—THE EDITORS.

HEADQUARTERS FIFTH DIVISION
OFFICE OF ASST. CHIEF OF STAFF, G-2

December 26, 1918.

HON. JAMES W. WASDWORTH, JR.,
The Senate, Washington, D. C.

My dear Jim:

When I saw you in Luxembourg I told you that there were some views that I had formed in regard to the army which I wished to give to you. At that time we discussed some of them. I am putting my views in writing in the hope that you may find them of assistance. They are the result of experience, observation, and discussion, much of the latter with Regular Army officers and them mostly general staff officers. Many of them I realize have no relation to legislation. I give them to you because your position on the Military Affairs Committee of the Senate makes it desirable that you know everything possible of the army. What I have to say is under the following headings:

(1) Highly trained officers.
(2) Promotion of officers.
(3) Reserve officers.
(4) Too many officers.
(5) From bottom up versus top down.
(6) Use of the specially instructed.
(7) The Infantry.
(8) The Regular Army.
(9) The localizing of regiments.
(10) Machine guns.
(11) Investigation.

I am not going to discuss conscription for I assume that the size of our army will depend upon the conditions of peace, nor do I discuss aviation although it will be essential that in knowledge and practice we keep abreast of every development in that line.

(1) *Highly trained officers.*—Knowledge is power, more so in warfare than in anything else. It gets results and gets them quicker, and it lessens the cost in men and material. The United States Army should have the most highly trained body of officers in the world. There should be the best of army schools and colleges. Army officers should be afforded every opportunity that can be availed of to learn. They should be encouraged and given the means to travel. All annual maneuvers of foreign armies should be visited and reported on by some of them for we all learn more by seeing and experiencing than by reading. Any amount of appropriation asked for along these lines should be granted. An indication of how insufficiently this was done before the war is that the annual appropriation for military intelligence was only $10,000. We have not yet as good and convenient maps and information in regard to Mexico for instance, as we could have.

Our officers should have exact and up-to-date knowledge of instruments of warfare and definite views as to their desirability kept up to date so that when trouble brewed, our experts would already have spoken and an investigation would not then have to be made. The general staff should have a definite plan of campaign for all reasonable contingencies of warfare in which the United States might become involved.

(2) *Promotion of officers.*—There should be an automatic system based on recorded efficiency, except in the highest ranks where a system of selection might be permitted. Automatic promotion by seniority should go by the board.

To my mind this is the most vital question for the army, for everything else rests upon it. A most burdensome problem in the A. E. F. was what to do with the too highly promoted regulars. Many were majors or higher whom army men knew were unfit and should have been eliminated before. The Blois system was instituted and made it possible to get rid of them, but not until they had done harm. This difficulty in the army is merely typical of the difficulty throughout the government service.

The best solution is to give advancement to capable men while they are young, basing that advancement automatically on records and examinations.

The officer who shows capacity for leadership should be advanced a certain number of files therefor. Each regiment might be given the privilege of maintaining one or more officers at the schools and those officers advanced a certain number files according as they did well at the schools. Schools have kept life in our officers and were found essential in this war. Particularly should advancement be given to men who show initiative and a readiness to assume responsibility. It may be that special advancement should not be made until an officer reaches 30 so as to give all a chance to develop and submit all to the test of several years service.

This would mean that the younger men of ability, initiative, and responsibility would be pushed forward and as they grew older would be at the top. There should be a liberal system of retirement so that a man who saw that he was not going to get far would be tempted to get out, which would tend to keep only the efficient in the army.

Congress will have to legislate on this subject in some way for the army cannot be relied upon to be its own saviour in this matter. There are too many influences against it. It will operate against most of the officers, and as the majority are not to benefit by it the impetus must come from outside.

(3) *Reserve officers.*—Assuming that ours is to be an army to be expanded in case of necessity, every reasonable opportunity should be availed of to utilize the services of men who are not in the Regular Army. A considerable attempt has been made to do this in this war. I have been a most lucky beneficiary of that attempt and when I say that it has not been availed of as fully as it might have been, I speak from what I have seen in regard to others and not what I have experienced myself.

This war was a G-1 war, that is, a question of supplies and transportation. The more efficiently these were handled the more the American Army could accomplish, for our men could not be stopped and the principal question was that of getting them food, ammunition, clothing, and other necessary equipment.

During times of peace, therefore, men who have to do with transportation, men employed by corporations, and contractors who have problems of getting material over bad roads in a limited amount of time, to name only a couple of classes, should be invited to study staff work and in maneuvers to operate as assistants under regular officers so that, in case of war, when the army expanded, their abilities and civil training could be utilized to the full and they could start with a knowledge of army routine and the army way of doing things which it takes some time to acquire and the lack of which interferes with men's usefulness.

Similarly, college professors, architects, and lawyers could be trained in the Intelligence branch.

In this way regular army officers could be saved more and more for that which requires the greatest amount of training, namely the tactical leading of men. In this connection the suggestion has been made to me that West Point should be greatly enlarged, it being understood that a large percentage of the graduates would pass into civil life and become reserve officers, preferably after having served half a dozen years in the line and so have learned instinctively how to handle men and maneuver them tactically.

For this leadership of men in actual fighting we must look first to the Regular Army or reserve officers thoroughly trained as these would be. Every regular young officer should serve at least six years in command of troops, passing through the grades up to captain.

(4) *Too many officers.*—We have too many officers. This is not true of the command of line troops. It is true, however, of the work around the staffs and of the work in the S. O. S. If the number of officers we have is compared with the number in a French staff it will be found that much of the work for which we use commissioned officers is with them done by privates or non-commissioned officers and done quite as well if not better.

Many of the men who are not officers are better than many who are. While this discrepancy might disappear in the course of a long war it is likely to be very apparent in a short war. To have commissioned officers where others will do leads to feeling against the army and in my opinion very properly so.

It gives a chance to the demagogue to claim that the privates are those who suffer the losses when as a matter of fact the losses among line officers are much higher in percentage than the losses among privates and non-commissioned officers.

Moreover, the young man of patriotism, who immediately enlists finds a less patriotic man who has hung out for a commission doing work which he could better do. The position of the noncommissioned officer should be increased in dignity and comfort.

(5) *From bottom up versus top down.*—One criticism which I have frequently heard made and in which I think there is great justice is that things are done too much from the top down without sufficient consideration of those who are below. Apparently the delight of the staff officer is to issue orders. Some of them are issued with insufficient consideration and with lack of knowledge. Instead of learning and instead of getting suggestions from those who have got to do the practical work, the order is given based upon an idea that has floated into the brain of the superior staff officer.

A man is a better staff officer who has actually commanded troops in war and knows the difficulties. A corps or army staff officer is more useful if he has served as a division staff officer and knows its troubles. There is some irresponsible criticism of officers of the higher staffs. But innumerable instances could be gathered to justify the point I have made.

(6) *Use of the specially instructed.*—There was considerable waste in this war of men who were sent to specialist schools and then never used for the specialty although they had qualified. Many also who were selected by their immediate commanders for instruction as specialists were on the way wastefully diverted to other work. Something was wrong somewhere to permit this.

(7) *The Infantry.*—In all legislation in regard to pay, etc., it should be borne in mind that it is the infantry that does the fighting and that gains the ground, that holds it, that undergoes the greatest discomforts and suffers the heaviest losses. Everything else, artillery, aviation, cavalry, if such is used, etc., is auxiliary.

(8) *The Regular Army.*—It should be borne in mind that it was the regular army which set the American standard in this war. The fighting of the 1st and 2nd Divisions showed the Boche what he had to expect. Even where national guard divisions did well the Boche learned no such lesson as he learned from these regular army divisions which had the advantage of a higher percentage of regular army officers, had many who were volunteers and enlisted at the earliest and had given all their men the advantage of strict army training and discipline.

It was the aggressive fighting of these regular army divisions that convinced the French that our numbers were only a partial measure of the assistance our soldiers were to be and brought about the electric change in the morale of the French nation toward the war.

(9) *Localizing regiments.*—In order to arouse interest in the regular army, regular army regiments, brigades, and divisions should be localized at least by name, as are the baseball nines even though all those in them may not come from the locality. As it is now, the regular army suffers from the easy advertising which the national guard and national army regiments got because of local interest. There would also be a greater interest in the army if its regiments were localized. The experience of all other countries in this war shows this.

(10) *Machine guns.*—Every man and officer in the American Army should know how to operate every kind of a machine gun that there is and should be trained in the tactics of machine gun gunnery so that he picks the

proper positions for the location of the gun and knows how to use it tactically. The German Army is far superior in this respect to ours today for they have not treated the machine gun as something to be handled only by specialists but something which every man should know.

(11) *Investigation.*—The tremendous success that has attended America's efforts in this war is in danger of losing to her the many lessons which can be learned from it, especially from errors. This is true of military lessons for army men. Many mistakes were humanly made. They should be recorded. It is not pleasant to record mistakes and it is not likely that those who made them will do the recording.

It is not a matter which calls for a newspaper investigation but if in a non-sensational way a commission could be appointed, with an ample appropriation, composed of men whose one desire was to get at the truth and bring out the lessons to be learned, its report would be most informative. It would have many subjects, like the national guards, etc., of dispute to pass upon but there would also be many of tactical importance which, while they would be in themselves criticisms of individuals, would not arouse general hostility.

Sincerely yours,

HERBERT PARSONS.

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Effect of the Earth's Rotation Upon the Point of Fall

By Peter Field

(1) The interesting geometrical discussion in the May-August 1918 number of this Journal by Majors F. M. and C. W. Green suggests an analytical treatment. In conformity with the paper referred to the following notation will be used.

B = position of battery.
T = position of target.
t = time of flight when relative velocity of T and B is zero.
R = range or distance TB when T and B are relatively at rest.
E_r = radius of the earth.
ω = angular velocity of the earth i.e., .00007292 radian sec.
L = latitude.
δ = angle of fall.
Θ = azimuth of line of fire which for convenience in drawing the figure is taken counter clockwise.

As in the paper by the Messrs Green the problem to be solved will be: *Given a range R and time of flight t for the case when B and T are relatively at rest, what is the correction to R in case their relative velocity is not zero, assuming this can be obtained by finding the displacement of T with respect to B during the time of flight?*

(2) Let XY be the equatorial plane and count longitude from the meridian plane ZX. The positions of B and T are determined by their latitude and longitude which will be taken as (L,o) and ($L-\epsilon$, Δ). Their cartesian coordinates are (E_r cosL, O, E_r sin L) and ($E_r \cos[L-\epsilon] \cos\Delta$, $E_r \cos[L-\epsilon] \sin\Delta$, $E_r \sin[L-\epsilon]$). Relative to B, the point T describes a circle with angular

velocity ω. By projecting B and T on the XY plane it is seen that α, the initial angle which projection of BT makes with the X axis, is an angle such that

$$\tan\alpha = \frac{E_r \cos(L-\epsilon)\sin\Delta}{E_r\cos(L-\epsilon)\cos\Delta - E_r\cos L}$$

Now ϵ and Δ are small angles so that their cosines may be taken as unity and their sines equal to the angles in radians, also terms involving higher powers of ϵ and Δ may be neglected in comparison with terms involving only the first power.

Hence

$$\tan\alpha = \frac{E_r(\Delta\cos L + \Delta\epsilon\sin L)}{E_r\,\epsilon\sin L} = \frac{E_r\Delta\cos L}{E_r\epsilon\sin L} =$$

$$\frac{R\sin\Theta}{R\cos\Theta\sin L} = \frac{\tan\Theta}{\sin L}$$

The radius of the circle which T describes with respect to B is

$$E_r\sqrt{[\cos(L-\epsilon)\cos\Delta - \cos L]^2 + [\cos(L-\epsilon)\sin\Delta]^2} =$$

$$E_r\sqrt{\epsilon^2\sin^2 L + \Delta^2\cos^2 L} = R\sqrt{\cos^2\Theta\sin^2 L + \sin^2\Theta}$$

$$= R\cos\Theta\sin L\sqrt{1 + \frac{\tan^2\Theta}{\sin^2 L}} = R\cos\Theta\sin L\sqrt{1+\tan^2\alpha}$$

$$= R\cos\Theta\sin L\ \sec.\ \alpha.$$

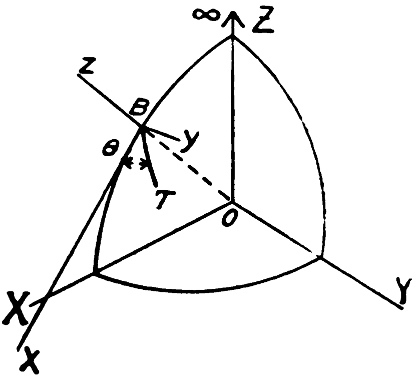

Fig. 1 2420

After a time t, T will have described with respect to B an arc ωt R cos Θ sin L sec α whose projections on OX and OY are

$R\cos\Theta\sin L\sec\alpha\,[\cos(\alpha+\omega t) - \cos\alpha]$ and

$R\cos\Theta\sin L\sec\alpha\,[\sin(\alpha+\omega t) - \sin]$.

The angle ωt may be treated as small so that the components of the displacement are $-\omega t\,R\tan\alpha\cos\Theta\sin L$ and $\omega t\,R\cos\Theta\sin L$.

(3) It will now be convenient to refer this displacement to the (x,y,z) axes whose direction cosines with respect to the old axes are as follows:

	X	Y	Z
x	$\sin L,$	0	$-\cos L$
y	0	1	0
z	$\cos L,$	0	$\sin L$

Hence the components of the relative displacement with respect to the x, y, z axes will be

$-\omega t\, R \tan\alpha \cos\theta \sin^2 L$, $\omega t\, R \cos\theta \sin L$, and $-\omega t\, R \tan\alpha \cos\theta \sin L, \cos L$.
If the displacements are resolved along the line of fire, at right angles to the line of fire in the xy plane (taking positive to the right as viewed from the battery), and normal to the xy plane, the components are

$-\omega t\, R \tan\alpha \sin^2 L \cos^2\theta + \omega t\, R \cos\theta \sin L \sin\theta,$

$-\omega t\, R \tan\alpha \sin^2 L \cos\theta \sin\theta - \omega t R \cos\theta \sin L \cos\theta,$ and

$-\omega t\, R \tan\alpha \cos\theta \sin L \cos L.$ The first component is zero, for

$$-\omega t\, R \cos\theta \sin L \left[\tan\alpha \sin L \cos\theta - \sin\theta\right] =$$

$$-\omega t\, R \cos\theta \sin L \left[\frac{\tan\theta}{\sin L}\sin L \cos\theta - \sin\theta\right] = 0$$

The second component can be written

$$-\omega t\, R \cos\theta \sin L\, (\tan\alpha \sin L \sin\theta + \cos\theta) =$$

$-\omega t\, R \cos\theta \sin L\, 1/\cos\theta = -\omega t\, R \sin L$, i.e., the deflection correction is $\omega t R \sin L$ to the right in the northern hemisphere.

The third component will be written in the form

$-\omega t R \sin\theta \cos L.$

It corresponds to a range correction $\omega t\, R \sin\theta \cos L \cot\delta$.

(4) The meaning of these corrections has been so fully discussed in the paper referred to that it is unnecessary to carry the problem any further but it seemed worth while to show that the results are readily put on an analytical basis. It should also be emphasized that the difference in these results and those given by Charbonnier, Cranz and others does not arise from the approximations introduced in the derivation but from the assumption, introduced at the outset, that the corrections can be obtained by finding the displacement of T relative to B during the time of flight. However they have the advantage of simplicity and, as stated by Messrs Green, if high angle fire is excluded they give results that agree fairly well with the more complicated formulae.

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The Defense of Paris Against Aeroplanes During the War

Translation from *L'Illustration*, March 22, 1919

By E. VILLARET, Major, C.A.

In previous articles, *Illustration* gave accounts of the damage done the capital by aeroplane bombing and by long range guns. But if the public now knows how our artillerymen, aided by our service of aerial information and by our sound ranging sections were able to locate and rapidly master the huge guns it knows but little of the effort made by the Anti-aircraft Defense, popularly styled the D.C.A., to reduce to a minimum the danger which menaced the Paris region from the incursions of hostile aeroplanes.

It may now be said that this effort was crowned with real success, and it is therefore only just to bring it to light. Moreover, figures taken from official documents establish clearly the disproportion existing between the immense effort made by the enemy and the feeble results which he obtained, that is to say between the risks run by the population of Paris and the actual harm it suffered.

I. THE ENEMY'S EFFORT AND THE CORRESPONDING DEVELOPMENT OF THE MEANS OF DEFENSE

Paris, seat of the government, with its suburbs, had a population about 1/12 that of all of France. It is thus a disproportionately large "heart" for the country. Too near the frontier in the beginning of the war and too close to the front during the period of stabilization, it constituted an objective that became all the more vulnerable as the density of its population and of its industries increased. It was therefore logical to expect that the enemy would make every effort to attack it via the air.

The attack was foreseen, and it will now be shown how the defense was organized, how it developed in the face of increased numbers and power of the planes which opposed it, and how, in spite of changes in the enemy tactics. it perfected itself.

The transformation of the defense comprises three distinct phases:

First Stage: 1914 - 1915 to beginning of 1916.—Aeroplanes: August, September, and October, 1914, and May, 1915—Zeppelins: March, 1915, and January, 1916.

At the beginning of the campaign bombardment by aeroplanes did not exist. Night bombardments effected from a distant base seemed limited to the Zeppelins. The defense therefore was organized almost exclusively against these. In consequence the aviation, which is the most efficient weapon against dirigibles, was largely developed.

At its inception the anti-aircraft artillery consisted of but a few guns. It was not definitely organized until 1915, and for some time thereafter it consisted only of improvised matériel.

Second Stage: End 1916 - 1917 to early 1918.—Toward the middle of 1916 the menace of night bombardment by aeroplanes in large numbers began to make itself felt. In 1917 the enemy having built some high powered "Gothas" sent them to England. The consequent heavy bombardment of London was an example which clearly indicated the necessity of reinforcing the defenses of Paris.

So, early in October of the same year, the D.C.A. (Anti-aircraft Defense) of the defenses of Paris took definite form, a regiment of anti-aircraft artillery being definitely assigned to it. At about the same time some Zeppelins, which were headed toward England, lost their bearings and were stranded in France. (Four Zeppelins were brought down.) This raid almost definitely marked the failure of the Zeppelins.

From then on only the aeroplane night bombardments were to be feared. And sure enough, early in 1918 the "Gothas" paid their first visit to Paris. At that time the defense of the aerial zone, just over the city itself, was assigned to the aviation, while the exterior defense was confided to the anti-aircraft artillery.

Third Stage: March, 1918 to November, 1918.—Big airplane raids o·· Paris by night. Reconnaissance during the day by a few airplanes.

The conditions under which hostile airplanes showed themselves were then as follows:

By day: Single machines at high altitudes, (500 to 600 meters).

By night: Powerful bombers, (large planes with 4 motors, Gothas, Friedricshafen, A.E.G. two motors) attacking Paris in successive waves at altitudes varying from 2500 to 4000 meters, in squadrons of 50 and even 70 planes, and generally on moonless nights.

The day defense continued in its former organization, the aviation making permanent patrols outside of the zone of action of the artillery. The batteries were considerably reinforced and regrouped to permit great concentration of fire.

As for the night defense, the co-operation of the aviation with the artillery presented great difficulties and even danger. It became very difficult to recognize the nationality of the airplanes in the fields of fire. In consequence, sound ranging on which this firing was based was hindered if not rendered entirely useless. The batteries were delayed in opening fire by the necessity for searchlight and light fuze recognition signals.

To avoid these difficulties, it was decided in March, 1918, to leave the field provisionally free to the artillery and to use airplanes only in case the artillery proved inadequate. At the same time, passive means of defense, of which more will be said later, were introduced.

II. ENEMY TACTICS IN APPROACHING THE CAPITAL AND ROUTES THAT HE COULD FOLLOW

The defense of Paris did not present the same problem as that of London: In case of an attack on England, the enemy crossed a large zone (the sea) above which nothing opposed his march, but the information received from the coast of France and from ships' searchlights, determined his intentions long before he approached the coast of England.

In order to reach Paris, on the contrary, the German aviators had first to pass through the zone of the front, which was well guarded, then through an intermediate zone in which their airplanes were met by ours, and to arrive at last in the zone, properly speaking, of the anti-aircraft defense. Thus their route from afar was no indication of the exact point of attack, and so their true intentions could not be determined until they were already very near the capital. Furthermore, it must not be thought that the enemy followed the valleys in guiding himself toward Paris, the water courses rarely being visible even by moonlight on account of the mists which gather in all valleys. He guided himself compass like, by following preferably the railways. These were clearly defined by the huddled dwellings, etc., and by the glow of locomotive fire pits which were much more visible than the signal flares (hidden by blinds from view of aviators) or than the dim lights of railway coaches, which, seen obliquely, produced only diffused light.

Until February, 1918, the enemy was guided above all by the luminosity overhanging Paris and its suburbs. This luminosity produced by the thousands of lights of the capital was comparable, according to our aviators, to that of the milky way. Even with restricted light this halo was visible, at an altitude of 3000 meters, from Villers-Cotterets in clear atmosphere.

In consequence serious police measures were taken to reduce this inconvenience to a minimum. The use of blue lights, which appreciably limits the visibility of sources of light, became general. Patrols extinguished the lights of vehicles, stores, and interior court kitchens of private houses. At the first alarm, factories with glass roofs and blued sheds (often painted in tints that were too crude) were plunged into darkness. But the railway stations, with their many red and blue signals, continued to be definite guiding points, and the same may be said of the long, straight avenues of the capital with their characteristic star shaped crossings, such as those at the Triumphal Arch, National Place, the Opera, and the Bastille.

III. Mission of the Anti-aircraft Defense

As even on the darkest nights the enemy could discover the capital, it was necessary to prevent his flying over it. But aerial attacks, like all attacks, can succeed only if they reach their objective without too great losses, i.e., if those who conduct it are not demoralized, much less paralyzed, by the means of defense.

Now it must be realized that, in order to bring down an airplane it is necessary to hit it in a vital spot, not simply to hit it. In so far as "Gothas," or similar night bombing planes, are concerned, a hit is not always sufficient to bring them down at once. This point is clearly established by numerous statements of enemy aviator prisoners. These have all testified that the German planes which were able to regain their lines after raiding Paris were in a large majority of cases seriously damaged by our projectiles after having attempted in vain to cross our barrages.

Under these conditions it is not by the destruction of enemy planes that one can judge whether the Anti-aircraft Defense has fulfilled its mission, but better by the number of times it has succeeded in imposing its will upon the enemy, that is to say forcing him to retreat before having attained his objective, and compelling him to drop his bombs in open country where their destructive effect is greatly reduced.

Such have been the results obtained by the Anti-aircraft Defense of the fortified area of Paris,—in proof whereof it may be stated that during 1918 the German air attacks always came to grief over the batteries, (on the periphery of the capital), the city receiving in each raid but a very small proportion of the bombs.

IV. General Organization of the Anti-aircraft Defense

The entire Anti-aircraft Defenses of Paris were placed finally under the single command of a general who had at his disposal:

1st. A special service of observers charged with signalling the approach of enemy airplanes from the greatest possible distance in order to give the defense time to make proper dispositions for combat.

2nd. An entire series of means of defense, whose zone of action extended clear into and directly overhead in Paris.

The Anti-aircraft Defense Command

The general who bore the title of Commander-in-Chief of the D.C.A. had a special Staff. He remained always at the headquarters of his command. As soon as a raid on Paris was announced, he went to a special room, fitted out as a command station, where the switchboard of the entire telephone system, and the service of information, were assembled.

In this room was a large mural map, showing all the elements of the defense, which enabled one to follow the enemy planes and all the phases of combat step by step. Thanks to an ingenious arrangement of direct communication with the elements of the defense and an automatic system of light signals, the progress of the enemy planes was indicated continuously on the map, as were also the entry into action, pursuant to their orders, of the different elements of the defense.

By these means the supreme command, kept posted constantly and without delay on the imminence of danger as well as of its termination, was in position to sound the alarm only for good cause and to limit the duration of this alarm to a strict minimum.

With so remarkable an organization, it is not surprising therefore that though from March to September, 1918, the Anti-aircraft Defense was on the alert every night, sometimes 3 or 4 times a night and that often the airplanes having advanced within range of the batteries had been engaged by the guns of the defense, it was possible nevertheless to spare the people of Paris a considerable number of annoying alarms and useless fatigue with all the accompanying emotion and anguish.

On all of these occasions the Command was able to determine in ample time that the danger to Paris had been avoided, and that the enemy had been repulsed by the advance elements of the defense.

Observation and Alarm Services

In order to keep the D.C.A. command thoroughly informed, a permanent service of observation of aircraft of all kinds was conducted in the following manner:

A vast system of special sentry posts (called lookout posts) was established all around Paris and extending as far as the Front.

This system permitted following all movements of the enemy planes as soon as these planes came within 80 kilometers of the capital.

Other posts, equipped with listening apparatus, would, so to speak, allow the enemy planes to sift through, and would determine their approximate altitude and route at great distances from Paris, even before they had come within range of the first line of A.A. batteries.

The telephone liaison necessary for the alert and inter-communication of the different elements of the defense, constituted an extremely complex system, whose perfect functioning was absolutely necessary both for putting the defense into operation in time to be of use, and for its efficacy.

For the purpose there were installed more than 6000 kilometers of aerial and subterranean lines. The supervision and upkeep of the lines were assured by specialists attached to the batteries, who were ever at hand to repair damages as soon as same were detected. They were assisted by patrols spread along the principal lines.

Finally, after each raid, the repairs made necessary by the damage done were completed the same day.

The service of P.T.T. (Telephone and Telegraph Co.) charged with the construction and maintenance of all these lines was obliged to put forth a very appreciable effort. This effort, to which it would be difficult to give the publicity and remuneration it merits, contributed greatly to the good work of the organization of all the defense.

Means of Defense

The means of defense employed by the anti-aircraft defenses of Paris in 1918 were of two kinds, 1st—Passive Means, 2nd—Active Means.

First—The Passive Means consisted either of placing obstacles along the probable routes to be followed by the enemy, which constituted for them a permanent and invisible danger (balloons), or of misleading him by means of reasonable camouflage of the terrain (emission of smoke and false objects).

For this:

(a) A number of kite balloons with various anchorages were distributed at various points in the vicinity of Paris and in Paris itself. On the alert signal these balloons were sent up to high altitudes, in order thus to block most of the routes habitually followed by the enemy.

(b) Smoke, generated by special machines, was emitted, thus permitting the masking at the most propitious moment of the guide points which might be used by the enemy, also for the purpose of modifying the characteristic lines of the ground.

(c) To the organization of camouflage by smoke generators there was added the establishment of false objectives consisting of frail structures (a kind of false scenery) installed at various distances from Paris at points not vulnerable. An ingenuous disposition of lights enabled a normal activity of all these false objects to be simulated.

(d) Finally, the lighting of Paris and its environs, already limited before February, 1918, was reduced to a strict minimum. After this date in case of alert, the darkness was practically absolute.

Second—The Active Means consisted of a methodical and continuous chasing of enemy planes, by following their evolutions in order to impede their progress, and to inflict injury upon or to destroy them. (Aviation, anti-aircraft artillery, searchlights, and machine guns.)

All of these means, put into instant operation, thanks to the excellent organization of the D.C.A. telephone system, contributed, each its part, to the general defense, but the anti-aircraft artillery played the principal rôle.

V. ANTI-AIRCRAFT ARTILLERY OF THE FORTIFIED AREA

The Artillery of the defense had a problem that was very difficult of solution.

Imagine a swarm of invisible planes, heavily laden with bombs and torpedoes, converging toward Paris in the dead of night, from all points of the compass, and moving with the speed of meteors, at altitudes as great as 10 to 15 times the height of the Eiffel Tower. The problem of the defense consisted of determining the number of enemy planes and of opposing to each a heavy yet efficient gunfire. In order to accomplish this end, each battery of anti-aircraft artillery, by means of a complex but minutely studied system of communication, was able instantly and automatically to use the unfaltering stream of information from all stations, and the centralized arrangement of these stations enabled the determination of effective firing data.

The Efficiency of the Anti-aircraft Artillery at Night

The question has often been asked: "How is it that the anti-aircraft artillery, which during the day seems to have only a relatively small efficiency, even though the gunners can see the target, becomes so redoubtable at night, when the target no longer being visible, the gunners are reduced to location by the sound of motors?"

There are several reasons for this apparent anomaly.

First—During the day the reconnaissance or photographing planes lightly weighted fly at very high altitudes (5000 to 6000 meters). At these altitudes each battery has but a very much reduced field of fire. Furthermore, it is impossible to see the airplanes clearly at such heights, even in good weather, owing to the dazzling light of the sky, whereas the aviator easily sees objects on the ground.

On the other hand, at night, the large bombing planes, heavily laden, not only with bombs, but also with a large quantity of gasoline and oil, cannot attain these high altitudes and therefore fly at about 3000 meters. At this altitude the artillery has a large field of fire and the fire of many batteries will always intersect and can be concentrated simultaneously on the same target.

Second—By day, the enemy planes have no fear of losing direction. They can take various routes to escape the fire of the artillery and throw it off the track.

At night they do not have this advantage; they fear above all being lost, because they fly by compass, and the terrain serves only to verify their route. Therefore they fly a straight course pointing directly at the objective, so long as they are not obliged to dodge or execute turning movements.

Third—At night the sound of motors is heard much better than by day. Thus, sound ranging is conducted under much more favorable conditions at night: in fact, an airplane heard at long distance can be located and its altitude determined accurately before it comes within the field of fire of the battery.

The Searchlights

It has been asked also why it is the artillery fires by sound at night, when powerful searchlights, by making the planes visible ought to permit of direct firing. In the first place, it must be said that the illumination of an airplane by a searchlight is a difficult problem, it being based like artillery fire, on the exact location by sound of the successive positions of the plane in space. But the sound is not instantly heard. It travels through space at a speed scarcely 10 times that of the airplane.

The result is that an airplane located at a certain point has moved some distance from that point when the sound made by the motors at that point is heard. Therefore it would be useless to illuminate this point, whence it is necessary to predict the proper position to illuminate somewhat forward of the plane and in prolongation of its route.

This problem has been solved, and what is more, it has been possible to keep the airplanes in the beam of the searchlights and to follow them through all their evolutions. But, whereas an unilluminated plane flies in approximately a straight line, a plane that is surprised by a searchlight defends itself by changing its altitude and by modifying its course, in so far as is compatible with its load and its mission.

Finally, an airplane caught in the beam of a searchlight at 6 to 8 kilometers is almost imperceptible to the gun pointers who, in addition, are blinded by the blast of each shot.

Thus the gunfire is limited to that which is based on sound only, the searchlights having for their mission the blinding of hostile aviators, preventing them from seeing their guiding points on the earth, and compelling them to change their course to escape the great confusion caused by the luminous beam placed on them.

Fire by Sound

In night firing, the rôle of the gun pointers and gun crews may be compared to that of the torpedo personnel of a submarine, or in general of any warship: these men see nothing and hear nothing, except the commands of the C. in C. who, alone, sees and hears. They can but execute scrupulously and blindly the orders received, and even so, only at a precise instant.

It is under these conditions that a torpedo strikes its target, i.e., at the predicted moment of the passage of the hostile ship. It is under these conditions also, that a shell hits an airplane. Only, the problem of the anti-aircraft artilleryman is still more complex than that of the seaman, because of the high altitude and the great speed of the target.

To compare still further: if the personnel in the hold of the warships corresponds to the gunners in the A.A. battery emplacements, the directing personnel officers in the conning tower correspond to the officers of the anti-aircraft artillery in their "acoustic center" or command station. It is there that the listening apparatus which permits the continuous determination of the route of the airplanes is installed. This station is somewhat of a laboratory in which extremely delicate but very accurate deductions are made by means of a complex telephonic organization, and of graphical charts and ingenious devices evolved during the war. Thus the instantaneous solution from precise acoustic apparatus of the altitude of a plane, its path, and the exact position it must occupy at a given moment, is made possible.

Finally, firing orders transmitted to the guns by telephone, are faithfully executed, and at the predicted instant, and predicted point, there is thrown before the airplane an impassable wall of fire into which it inevitably must go.

And thus it is that the enemy airplane, after having been thrown against the barrages several times and after having been compelled to change direction several times, winds up by losing its bearings, gives up the struggle, quickly drops its bombs over the last battery which has engaged it in action, and flees, nearly always injured, always defeated.

VI. The Results

To judge of the results obtained by the anti-aircraft defense it suffices to but glance at the following table. Its story renders comment unnecessary, but precisely on that account it is all the more necessary to point out how it has been possible to accomplish these results.

The paths of the airplanes and their number were determined by the juxtaposition of the graphical tracks obtained by accurate acoustic methods of observation at the batteries for each plane or group of planes fired upon, the graphs being checked against the reports submitted from all the other elements of the defense.

NIGHT RAIDS BY ENEMY PLANES IN THE PARIS AREA DURING 1918.

Night of	Number of Enemy Planes in raid	Number of Planes succeeding in flying over Paris itself	Number of Bombs dropped on Paris						Planes Brought Down by the Defense.
			Planes	Kilograms					
				300	100	50	10	5	
Jan. 30-31	30	11	2 7 1 1	2	7 1 1	35 2	11 20	12	1 Plane brought down near Chelles.
Mar. 8-9	60	3	1 2		2 2	2 10	6 2	2	
Mar. 11-12	70	5	4 1		4	16 1	18		4 Planes, struck by AAA, could not reach their own lines and had to come down in the region Chateau-Thierry, Soissons La Férre, Milon.
Apr. 1-2	7	1	1			5	7		
Apr. 11-12	2	2	1 1	1		6			
Apr. 23-24	1	None							This plane was obliged to land near Nogent-l'Artaud.
May 15-16	30	None							
May 17-18	3	None							
May 21-22	10	1	No bombs						1 Plane, disabled by AAA, landed near Verberie.

May 22-23 2 attacks	40	1	1		1	5			
May 27-28	15	None							
May 29-30	5	None							1 "Gotha" violently engaged by AAA brought down in flames at Plessis-Belleville.
May 30-31	6	1	1	1		1		4	
31-June 1 2 attacks	6	None							
June 1-2	11 (2 of which are Giant Planes)	2 (on periphery of Paris only)	1 1	1	1	4			1 of the Giant Planes violently engaged by 4 AAA btys. brought down at Betz. The crew of 3 officers & 7 men set fire to the plane & are made pris.
" 3-4	7	None							
" 6-7	20	2	1 1		2	1 1	10 30		
" 13-14	3	None							
" 15-16	10	1	1			7			
June 26-27	20	1	1			6			
June 27-28	40	2	1 1		1 1	5 5	5 4		2 Planes struck by the AAA were brought down: one of them near Villers-sous-Coudun, the other in Eagle Forrest. A 3rd plane, disabled managed with great difficulty to get back to own lines flying at very low altitude.

NIGHT RAIDS BY ENEMY PLANES IN THE PARIS AREA DURING 1918.

Night of	Number of enemy planes in raid	Number of Planes flying over Paris itself	Number of Bombs dropped on Paris						Planes Brought Down by the Defense.
			Planes	Kilograms					
				300	100	50	10	5	
June 28-29	2	1	No Bombs						
" 30-July 1	4	None							
July 1-2	3	None							
July 18-19	10	None							
Aug. 1-2	10	None							
Aug. 15-16	10	None							
Sept. 15-16	50	3	1 1 1		1	4 7 7	6		2 Planes brought down. One by direct hit which cut it in two while it was coming toward Paris at an altitude of 3200 meters: one of its motors was blown off and it came down straight just north of Gonesse. The other plane fell in the Comiegne Forrest.
1918	483 planes	37 Reached Paris	and drop	5	24	130	119	18	And lost 13 Planes brought down.

All of these reports, checked immediately after each raid by different authorities who do not communicate with each other, always yield remarkable concordant information which, compared with the official reports of the points of impact of bombs, are in perfect accord with them. The compilation of these reports thus constitutes an analysis having the semblance of certainty.

The thrills of night alarms, the sinister call of sirens, the thunder of barrages, are memories now eclipsed by the daze of the complete victory crowning the wonderful effort of the allied armies. But the Parisians whose morale proved so high when subjected to the test, will always retain a feeling of deep gratitude for the D.C.A. which, with the aid of the aviators of the fortified area of Paris contributed so much to the defense of the capital and in consequence the entire country.

A first tribute of admiration is due the aviators, who, for four years, assured the security of the City: by continuous patrol by day, and at night, in facing the dangers of flying and landing in pitch darkness under the most trying conditions. Up to March 1918 by which time it was realized that the results obtained under such conditions were not compatible to the sacrifices entailed, they accomplished their perilous missions with the greatest fearlessness.

The homage owing to the aviators may be confused with that which is due to the staff and personnel of the D.C.A. But let it be said in passing, that this service had to be created in its entirety on short notice and that it was composed almost exclusively of old men and of wounded men who already had paid in large part their debt to their country.

It never will be realized how much work devolved on the officers who were charged with the hurried yet technical instruction of such units and such soldiers from whom despite their disabilities there was exacted that absolute precision of action without which the defense would have lacked efficiency.

Neither will it be possible ever to find terms sufficiently strong to laud the cheerful willingness shown by these men who responded so nobly to the confidence which the country placed in them.

Watchers at the information posts, whose unceasing vigilance was one of the principal causes of the moral tranquility of Paris. Artillerymen at the batteries, and searchlight details always ready to run at the first alarm to their combat stations with all the agility which their age and war-inflicted infirmities permitted; called upon to remain immovable entire nights in all kinds of weather; at times even holding their breath, the better to discover the presence of the enemy who was invisible in the silence of black night. Telephone operators at their trying and all absorbing work; machine gun, balloon, and camouflage personnel, always ready.

In spite of the fatigue endured and of the long intensive hours, especially when the enemy's armies were threatening the capital, they maintained the highest conception of their duty.

Glory to their eminent chiefs, to all those who prepared the organization and who, during the darkest hours of 1918, gave their utmost in completing and augmenting that organization that it might successfully meet the situation. Among these, special mention is due the general who watched over the capital, who with eyes on the map on which appeared both the enemy's movements and the results of his orders to the stations of defense awaited the propitious moment for directing the sounding of the sirens. How frequently he took upon himself the responsibility of not troubling the sleep of the people in gauging that the attack had been broken.

In conclusion, if the barberous projects of the Germans who, in exasperation at their successive failures, had sworn to reduce the capital to cinders, were not realized it was due to the power of the anti-aircraft defense, whose work may be summed up in these terms: Paris was to have been ravaged by the enemy aviation; Paris was not so ravaged.

From the table it is seen that of 483 planes employed by the enemy during 1918, only 37 succeeded in flying over Paris and that 13 were brought down by the Aircraft Defenses. (D.C.A. De'fense contre Aeronefs.)

Note.—It is interesting to recall that following the last raid on Paris, a German radio message announced that: "By way of reprisal for the bombardment of German towns, 22,000 kilograms of bombs were dropped on Paris during the night of September 15-16." As a matter of fact only 1060 kilograms were dropped on Paris during this raid. Furthermore, during the whole of 1918, a total of only 11,680 kilograms of bombs fell on Paris; that is to say only half of what would have been dropped on it during the single night September 15-16, but for the efficient protection given by the D. C. A.

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Armored Trains for Coast Defense

In the early months of the war it was recognized that it was desirable that there should be armored trains for coast defense, especially on the East Coast, and two such trains were provided, one for the East Anglian Coast and one for the East Coast of Scotland.

The request for these trains was received from the War-office by the Railway Executive Committee, which referred it to the War Manufactures Sub-committee. The bare outlines only of what was required were furnished, and the details were left to the Sub-committee, which decided that the engines should be supplied by the Great Northern, the infantry vans by the Great Western, the trucks for the gun carriages by the Caledonian, and that the London and North-Western should construct the upper part of the gun-carriage at Crewe and complete the train.

The engine is in the middle of the train, the infantry vans on either side of the engine and the gun-carriages at the ends. The engines were, as we have said, supplied by the Great Northern. They are 0-6-2 tank locomotives, of that company's London Metropolitan District type, with condensers, and bear Nos. 1587 and 1590. They have 18 in. by 26 in. cylinders, boiler pressure of 175 lb. per square inch, engine wheels of 5 ft. 8 in. diameter, trailing wheels of 3 ft. 8 in. diameter, wheel-base 23 ft. 9 in. length over buffers 36 ft. 4-½ in., tank capacity 1600 gallons, bunker capacity 4 tons of coal, weight in working order 76 tons, 19 cwt. They are armored in all parts above the framing, whilst the machinery below, vacuum brake, etc., are also protected. The cab windows are furnished with metal sliding shutters, and a special look-out is provided on each side of the cab.

The infantry vans were converted by the Great Western Railway from that company's 40-ton coal wagons, the armor being ½ in. thick for the sides and 3/8 in. thick for the roof. One van is open throughout, whilst the other has officers' quarters partitioned off. In the sides of each van are twenty-eight rifle loopholes, provided with sliding doors, and inside the van, next the door, two rifle racks, one on each side, containing space for ten rifles each. Along the greater length of the sides of the interior of the vans are lockers. In one van are two tanks, each of 50 gallons capacity, for drinking water, and in the other van two bunkers, each of one ton capacity, for coal for the engine. Under the latter van there are four tanks, each of 200 gallons capacity, for feed-water. Each van has a coal fire cooking stove, with pipe through the roof, and a latrine. At each side and end is a sliding door. The total weight of the van complete, when armored, is 30 tons, 17 cwt.

The gun trucks were each built at Crewe on 30-ton trolley wagons supplied by the Caledonian Company. The gun truck has three compartments: Maxim gun compartment, ammunition compartment, and the gun platform. The Maxim gun compartment is that nearest the engine. In order to give play for the Maxims it is especially shaped, being 5 ft. 4-½ in. wide at the engine end, and tapered thence for 2 ft. 9 in. to 9 ft. wide for a distance of 3 ft. Thence it is tapered inwardly to a width of 7 ft. 8 in. for 6 ft. 8-¼ in. The ammunition compartment is of the latter width for 6 ft. 8-½ in. and then tapers in 3 ft. 8 in. to 4 ft. 6-½ in. The gun place is 11 ft. 10-¾ in. long, and is at the widest part 9 ft. wide for a distance of 8 ft. 2-11/16 in. The height of the Maxim gun and ammunition compartment in the center is 6 ft. 10-7/8 in. inside from the floor and the top of the floor is 3 ft. 4-½ in. above rail level. The height outside at the sides is 9 ft. 5-¾ in. above rail level.

Between the Maxim gun and ammunition compartments sliding doors are provided, but the vehicle is entered from the infantry van by a single door, 2 ft. wide, opening outwards. On each side of the Maxim gun compartment and close to the division from the ammunition compartment is a door 2 ft. 6 in. wide opening inwardly. Between the ammunition compartment and the gun platform is a pair of doors, each 1 ft. 6 in. wide, opening into the ammunition compartment.

On each side of the Maxim gun compartment are three observation holes, 8 in. diameter, with doors, two rifle loop holes, 12 in. long by 4 in. deep, with sliding doors, and three openings, 1 ft. 3 in. square, for the Maxim; also a cupboard with 2000 rounds of Maxim ammunition, whilst on one side of the door from the infantry van is a cupboard containing 1000 rounds of ammunition, and on the other a 10-gallon tank for the Maxim cooling water. Behind each side door is a cupboard 3 ft. wide with a drawer above it. In the center is a coal stove for heating purposes.

The ammunition compartment has on each side one observation hole and one rifle loop-hole in the angle in front, one observation hole over the door to the platform, and two rifle loop-holes in the side. Along each side is an ammunition cupboard, 6 ft. 8-½ in. long, 2 ft. 1 in. wide and 3 ft. 9-½ in. high. The cupboard contains fifty pigeon holes, each holding two 12 pdr. shells, and the remainder of the cupboard is spaced for ten cases of cartridges, each containing ten rounds.

The front and sides of the gun platform are 2 ft. 11-½ in. high, of which the upper 1 ft. 4 in. is hinged, and falls inwards in No. 1 train and outwards in No. 2 train. In the hinged plates are four rifle sight holes on each side and three in front. The gun, which, with its mounting, is the only part of the train not supplied by the railways, was a 12-pdr. quick-firer, Mark

IL. The weight of the gun-carriage in working order, including armor, is 37 tons, 13 cwt.

The train is lighted by acetylene, for which a carbide generator is provided in each van. There is a telephone on the engine, and one in each ammunition compartment. The train can be driven from the engine or from either end, as the regulator is controlled by a communicating chain running through all the vehicles. All the vehicles are provided with communicating gangways and the vacuum brake. The latter, the coupling chains and the wheels are protected from the floor level of the vehicle to within 9-½ in. of rail level by 5/16 in. steel plates.

The first train was put together very quickly after the various units had been received at Crewe, and ran its trial trip from Crewe to Chester and back on December 26, 1914. Train No. 2 was not ordered for many months afterwards, and was delivered on May 2, 1915. Train No. 1 was known as H.M.T. Norna.—*The Engineer.*

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Jellicoe on the Grand Fleet

Reprinted from the Scientific American

Seldom, if ever, has the commander-in-chief of naval or military forces given to the public so candid and illuminating a story of his war experiences as is found in the 500-page volume, written by Admiral Jellicoe and published by the George H. Doran Company of New York City, under the title "The Grand Fleet." The book produced a positive sensation upon its first publication in London—as well it might; for the British people learned for the first time upon how slender a thread, in the first few months of the war, hung the fate, not merely of the British Empire, but of the whole Allied cause.

The work has been spoken of as an "apologia;" written for the express purpose of defending the author against criticisms of his strategy and particularly of his tactics in the famous battle of Jutland; but we are free to confess that a careful reading of the book has left no such impression upon our mind. Rather we carry away the impression of a straightforward story, told with characteristic "sailorman" frankness, of the day-by-day experience of the fleet, as viewed from the position of its commander-in-chief. Had the Admiral been writing a private diary of the war, he could scarcely have been more frank in his statements of defects in strategy that had evidently been imposed upon him from without, or in his revelation of the unpreparedness, both of the Grand Fleet and of its naval bases in the North Sea, for the stupendous task with which it was so suddenly confronted.

And reading between the lines, those of us who follow the course of naval affairs in the United States, are able to place the blame for unpreparedness where it belongs. It was not the fault of the Jellicoes, the Percy Scotts, and the Beattys of the British Navy that the Grand Fleet, short of destroyers, short of submarines, short of scout-cruisers, short of up-to-date range-finders and searchlights, was ordered to Scapa Flow, an utterly unprotected base open to destroyer and submarine attack—no more their fault than it was the fault of our own Deweys and Simses and Fiskes that our battleship fleet was less than one-half of its proper and necessary strength, and that the fleet we possessed was wofully short of scouts and destroyers, and had no battle-cruisers whatsoever.

So long as naval appropriations are made the sport of the politicians, a great naval power like the United States or Great Britain will be continually faced with the possibility of disaster. And so long as a politician like Churchill can force a Grand Fleet to do its coaling in an open and undefended harbor opening onto submarine-infested waters, or bring strong pressure upon that fleet (as Churchill actually did) to engage in such a mad venture as a bombardment of the Heligoland forts, the morale, even of the high command, will be disturbed and their sureness of themselves and their strategy shaken.

It is amazing to learn how slight was the superiority in capital ships and how decided the inferiority in destroyers and light cruisers of the British to the Germans in the North Sea during the early months of the war. Being the blockaded fleet, the Germans could elect to come out when every ship of the High Seas Fleet was in perfect shape. The British, due to continual cruising in one of the stormiest of seas, always had some ships undergoing refit or repairs. Thus, Admiral Jellicoe tells us that towards the close of October the Grand Fleet was considerably weakened, apart from the fact that it had lost the "Audacious." The "Ajax" had developed condenser defects; "Iron Duke" had similar troubles; the "Orion" had to be sent to Greenock for examination of the turbine supports, which appeared to be defective; the "Conqueror" (all of these it should be noted are dreadnought battleships) was at Devonport refitting, and the "New Zealand" was in dock at Cromarty. The "Erin" and "Agincourt," having been newly commissioned, could not yet be regarded as efficient; so that the dreadnought fleet consisted only of 17 effective battleships and five battle-cruisers. The German dreadnought fleet at the time comprised 15 battleships and four battle-cruisers with the "Blucher" in addition. Everyone will agree with the Admiral when he says, "The margin of superiority was therefore unpleasantly small in view of the fact that the High Seas Fleet possessed 88 destroyers and the Grand Fleet only 42."

Admiral Jellicoe says that he often wondered why the Germans did not make greater efforts to reduce the British strength in capital ships by destroyer or submarine attacks on the British bases during those early days. "They possessed," he says, "in comparison with the uses for which they were required, almost a superfluity of destroyers, certainly a superfluity as compared with ourselves, and they could not have put them to a better use than in an attack on Scapa Flow during the early months of the 1914-1915 winter."

Speaking of the frequently-made suggestion that the Grand Fleet should make an attack upon the High Seas Fleet at anchor in its home port, he says: "They not only possessed the most powerful and ample artillery defenses, but we knew also that the Germans had a very efficient mining service, and we were justified in assuming that they had protected their naval bases by extensive minefields. We, on the other hand, were entirely unprovided with this particular form of defense."

Taken altogether, it is evident that the Germans missed their great opportunity at this very time. How they failed to know of conditions at Scapa Flow is puzzling, to say the least. The Zeppelins should have provided this knowledge. The Admiral's own suggestion is that "it may have seemed impossible to the German mind that we should place our fleet, upon which the Empire depended for its very existence, in a position where it was open to submarine or destroyer attack." Reading between the lines it is very evident that Admiral Jellicoe and his staff were not responsible for the selection of Scapa Flow as the naval base in those perilous days.

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History of the Railways and Roads Training Center, R. E., Longmoor. The Royal Engineers Journal, July, 1919, p. 28.

High-Burst Ranging. Professional Memoirs, May-June, 1919, p. 279.

How the Navy Designed and Built the World's Heaviest Field Piece. The Bureau of Ordnance brings out an entirely novel type of mount for a seven-inch navy gun for the U. S. Marines. *United States Naval Institute Proceedings,* July, 1919, p. 1159.

Improved Type of German Pill Box. Professional Memoirs, May-June, 1919, p. 253.

Infantry Guns. The Journal of the Royal Artillery, June, 1919, p. 124.

Keeping the Big Guns at the Front Effective. The mobile repair shops of the U. S. Army Ordnance Department. *Scientific American,* July 26, 1919, p. 88.

Reinforced Concrete Shelters of German Hindenburg Line. Professional Memoirs, May-June, 1919, p. 312.

Sunken Battle-Cruiser "Seydlitz", The. Scientific American, July 26, 1919, p. 91

Survey in France During the War. The Royal Engineers Journal, July, 1919, p. 1.

Torpedoplane, The—The new weapon which promises to revolutionize naval tactics. *Flying*, August, 1919, p. 597.

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Library, Coast Artillery School,
Fort Monroe, Virginia.

Agencies for the sale of cooked foods without profit. (1919)	Council of National Defense.
Alexander letters, The	1787-1900.
American ephemeris and nautical almanac, The (1921)	U. S. Nautical almanac office.
Appletons' new Spanish-English and English-Spanish dictionary. (1919)	Cuyas, Arturo.
August the fourth, 1914, in the Belgian parliament. (1918)	Lichtervelde, Louis de.
Bullingers' postal and shippers guide for the U. S. and Canada. (1918)	Bullinger, Edwin Wilson.
Calculation and measurement of inductance and capacity, The	Nottage, William Hockley.
Cartography. (1918)	U.S. Coast and geodetic survey.
Colonial Virginia	Chandler, Julian A. C.
Conquest and Kultur, (1918)	Notestein, Wallace.
Conquest of Virginia:	Sams, Conway Whittle.
Course for sheet metal workers	U. S. War Dept. (Vocational training).
Description of the 32-centimeter gun and railway mount	U. S. Coast Artillery School, Fort Monroe, Va.
Description des decoration et des medailles estrangeres, La.	
Description of the U. S. Coast and geodetic survey tide-predicting machine no. 2.	U.S. Coast and geodetic survey.
Description, operation, and care of 5-kilowatt portable gasoline-electric generating sets (Mathews type) Model G. (1918)	U. S. Engineer Dept.
Elements of astronomy; The	Young, Charles Augustus.
Elements of navigation Vol. 28 B	International library of technology.
Fighting the Boche underground (1918)	Trounce, Harry Davis.
Forts of Metz, The (1919)	Blake, E. M.
Gas turbine, The	Holzwarth, Hans.
General Joffre and his battles (1916)	Recouly, Raymond.

Geodesy	U.S. Coast and geodetic survey.
Goedesy. Investigations of gravity and isostasy	U.S. Coast and geodetic survey.
Geodesy. Latitude observations with photographic zenith tube	U.S. Coast and geodetic survey.
German treatment of conquered territory	Munro, Dana C.
German war practices	Munro, Dana C.
Guide to the use of United States government publications	Clarke, Edith E.
How the war came to America	U.S. *Committee on public information.*
Hydrography. Wire-drag work on the Atlantic coast	U.S. Coast and geodetic survey.
Hypsometry. Use of mean sea level datum for elevations	U.S. Coast and geodetic survey.
In the path of the Persian (poems)	Magister, Stephen.
Knots, bends, splices, with tables of strengths of ropes	Jutsum, J. Netherclift.
Logarithms of hyperbolic functions to twelve significant figures	Pernot, Frederick E.
Mastery of the Far East, The	Brown, Arthur J.
Military character	U.S. Naval War College.
Military English 1918	Long, Percy Waldron.
Military landscape sketching and target indication	Newton, W. G.
Military map-reading simply explained	Lynam, W. P.
National service handbook	U. S. *Committee on public information.*
Nautical astronomy	International library of technology.
Naval artificer's manual, The	Pate, McCall, *comp.*
Navigation	Jacoby, Harold.
New encylopedia of social reform, The	Bliss, William D. P.
New international year book, The 1918	
Notes on dynamics	Greenhill, Alfred George.
Official congressional directory, 1918. (65th congress)	U. S. *Congress.*
Official catalogue of the Royal united service museum	Royal united service institution, *London.*
Pirate's progress, The	Archer, William.
Practical electricity	Croft, Terrell W.
Practical instructions relating to the construction and use of the steam engine indicator	Crosby Steam Gage and Valve Co.
President's flag day address, The	Wilson, Woodrow.
Register of the commissioned and warrant officers of the Navy of the United States and of the Marine corps. 1919	U. S. *Navy Dept.*

Report of the adjutant-general of the Commonwealth of Virginia for the year ending Dec. 31, 1918	
Report to the Chief of Staff. 1918	U. S. *Chief of Coast Artillery.*
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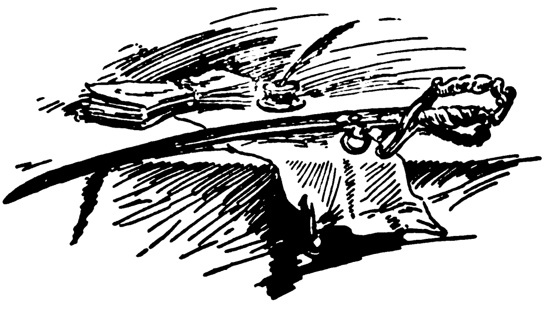
Spanish grammer, A	Ramsey, Marathon M.
Spanish nautical phrase book and reader, A	U.S. *Naval Acedamy, Annapolis*
Reference guides that should be known and how to use them	Hopkins, F. M.
Telephone directory of Philadelphia	The Bell Telephone Company of Pennsylvania.
Terrestrial magnetism	U.S. *Coast and geodetic survey.*
T N T as a blasting explosive	Munroe, Charles E.
Transactions 1919	Society of naval architects and marine engineers.
Treatise on analytical statics, A	Routh, Edward J.
United States official postal guide	U. S. *Post-office dept.*
Vaporizing of paraffin for high-speed motors, The	Butler, Edward.
War, labor, and peace	Wilson, Woodrow.
What to observe and how to report it	Hale, *Sir* Lonsdale A.
Who's Who. 1919	
Who's Who in America. 1918-1919	
Who's Who in Baseball. 1918	
Wiring for light and power	Croft, Terrell W.

NOTE: 114 Ordnance Pamphlets have been received and cataloged.



BOOK REVIEWS

Military English, Official correspondence, Orders, Messages, and Reports for Use in Courses Allied to Instruction in Military Science and Tactics. By Percy Waldron Long and Frank Wilson Cheney Hersey. New York. Macmillan Co. 5¼"x7¼". 116 pp. Price, $0.75.

From the title as quoted above, a very clear idea of the purpose of this book may be obtained. Some of the Chapter headings are: "The principles of Military English;" "Soldiers' letters home;" "Operation orders;" "Diaries;" and "Famous orders and examples of martial eloquence."

Under "Principles of Military English" particular emphasis is thrown upon precision, clearness, and brevity, all hingeing upon a habit of accuracy. As a proof of a thoroughly developed habit of accuracy the author states that "A thoroughly disciplined soldier should be able, during an enemy attack, to explain the movement of "Squads Right" without making a mistake." It is believed, in the humble opinion of the reviewer, that such an extremely well-balanced mind as the above test would necessitate, would be seldom met with in either commissioned or enlisted personnel of any army.

"Official correspondence" gives a very clear resumé of the requirements of G.O. 23, W. D., 1912, and refers to several more complete publications on the subject.

The chapter on "Soldiers' letters home," with its paragraphs on "Censorship," bring vividly to mind the weary nights of study over hurriedly scribbled letters in stuffy candle-lit dugouts, and brings a smile when one reads "Let him (the censoring officer) encourage Private X to write about such and such a story. Let him incite them all to write good leters..."and then when one remembers the stock phrases "Having nothing else to do I will write you a letter" "The censor is so d—n particular that I can't tell anything," and so on *ad infinitum*, and the patient hours spent in trying to explain to antagonistic minds the real need and use of censorship, the encouragement suggested seems to be a little beyond reach.

The chapters on Adminstrative Orders and Memoranda, Operation Orders, Field Messages, and Diaries, are all well worth close study, and the "Examples of Martial Eloquence" in Chapter X, from "Washington's Order of the Day Announcing the Arrival of the French Army" to "Marshal Petain's Order of the Day on the Surrender of Germany" furnish fitting examples of the points covered in the book.

The Treatment of War Wounds. By W. W. Keen, Md., L. L. D. Philadelphia. W. B. Saunders Company. 5½"x8¼". 276 pp. Profusely il. Price, $2.00.

This book by Dr. Keen is based upon a report to the National Research Council, and contains much information received from personal communications from surgeons in the war zone. The chapter on "The Carrel-Dakin Method" of treating infected wounds is quite full, going into detail of the preparation of solutions, as well as methods of procedure in its administration.

Various other war wound antiseptics such as, acriflavine, mercurophen, eusol, eupad, and dichloranim-T are described and discussed at length. The prophylaxis and treatment of tetanus by antitoxin, war shock, and gas gangrene are taken up in a short, but comprehensive manner.

Several of the newer procedures in the localization and removal of foreign bodies by the X-Ray are described. The chapter on burns is of particular interest.

The "No. 7 Paraffin" of Lieut. Colonel Hull, of the British Army is described in detail in this chapter.

It would appear from this book that Dr. Keen has used most excellant judgement in selecting for discussion the really worth while "methods and medicines in the treatment of war wounds." A great volume of reading would be necessary, as a rule to gain the information set forth in this little book of 276 pages.

Ambulance 464. By Julien H. Bryan. New York: The Macmillan Company. 5½"x7¾". 220 pp. 31 il. 1918. Price, $1.50.

Mr. Bryan, a Princeton Freshman, seventeen years old, went to the war and drove an ambulance in the Verdun and Champagne sectors. In this book he tells us all about it, explaining exactly what he heard and saw and relating many incidents and anecdotes of tremendous significance and interest. His account, which is brought down to August 1917, is modest, often times amusing, always vivid. The pictures illustrating the text are among the most remarkable war photographs to have reached this side. They shed new light on the war and its method of prosecution.

The Cadence System of Close Order Drill. By Lt. Col. Bernard Lentz, G. S. 1919. Geo. Banta Publishing Co. Wisconsin, 4½"x5½". 124 pp. Price $0.50.

A presentation of the development of the minutiae of close order drill during the war. The system is an extension of the principles of the I.D.R. rather than a modification of them. The purpose of the system is to increase the accuracy, snap, and interest of close order drill, and beyond that, *through* a vitalized drill, to step up the morale, "pep," and discipline of the organization.

The gist of the system is the idea, originated by Lieutenant Colonel Herman J. Koehler, of having all men in ranks give the commands for each movement, aloud, in unison, and in cadence. This idea, incorporated with other practical ideas contributed by various officers has evolved a system which succeeds in taking full account of the psychological factors affecting the soldier and the organization.

This little book is one of the books which the Coast Artillery officer, in order to be up-to-date, cannot afford to ignore.

What Every Investor Ought to Know. By Robert L. Smitley. New York. The Magazine of Wall Street. 4½"x6-1/8" 173 pp. Price, $1.00.

A book of especial value to the army officer, as it treats in simple fashion the basic principles underlying different classes of investments. Emphasis is laid all through the book on the importance of basing judgment on investments on sound knowledge rather than on chance or gossip.

To the officer unfamiliar with financial operations and the methods of merchandizing stocks and bonds, an illuminating and tersely presented guide is made available. Of particular value are the suggestions for the analysis of the value and safety of a stock or bond.

One chapter is devoted to measures for the protection of dependents, advice on the making of wills, and the uses of trust funds and trust companies.

Two valuable features of the book are the suggested courses in financial reading and the chapter on Liberty Bonds.

How to Select Investments. By F. Lownhaupt, G. C. Selden, G. G. Henry, W. H. Tibbals and J. J. Cushing. New York. The Magazine of Wall Street. 4½"x6-1/8". 148 pp. Price, $1.00.

This is one of a series of handbooks on investment published by The Magazine of Wall Street. The authors are well known in the financial world, and present their practical experience in concise, readable form.

This volume in the series is principally devoted to a discussion of bonds, what they are, their justification and use, the elements of safety and of risk in bonds, how to analyze their values, comparison of different sorts of bonds, and of bonds and stocks.

The JOURNAL especially commends to officers in the service the two chapters on "Legitimate Mining Investments" and "Mistakes of Investors."

War and Revolution In Russia, 1914-1917. By General Basil Gourko. The Macmillan Company. 5½"x8¾." 420 pp. Price, $4.00

General Gourko has written a most interesting account of his experiences in the Great War beginning with his service as a Division Commander and then thru higher commands to that of Chief of Staff. He gives us vivid impressions of the Russian commanders and of the Emperor, and of the almost hopeless immensity of the task assigned to Russia in the War.

Perhaps most valuable of all are the chapters devoted to the Revolution and the disintegration of the Russian Army. This destruction of his lifework along with the ruin of his country could be no less than heart-breaking, but General Gourko tells his story simply with no whining, proving himself a philosopher as well as a soldier.

The Soul of Ann Rutledge. By Bernie Babcock. Philadelphia, J. B. Lippincott Company. 5¼"x7¾". 323 pp. Frontispiece in color. Price, $1.50.

This a story. But it is more than a story; it is a revealing chapter in the life of Lincoln. Many books have been filled with the thoughts and deeds of the most outstanding figure in American history, but the chapter of his early love has been almost hidden. The historical background for this romance of Lincoln is laid in fact. It is fitting that the first love of so great a man should have been for the noble, gifted, and beautiful woman pictured in the story.

This book is splendidly written, and without losing the accent on its main theme, flashes clear pictures of the frontier days and the pioneer people of Illinois in the early part of the last century, a picture of the life which was the foundation of our own, and which we have almost forgotten.

China and the World War. By W. Reginald Wheeler. New York. Macmillan Co. 5"x7¾". 263 pp. Price, $1.75.

The struggle of the Chinese to establish a republic should hold a deep interest for the American people. Professor Wheeler shows us how greatly are China's difficulties increased because of the aggressiveness of Japan and her desire to become the guardian of the Orient. China's service to the allies is reviewed and a long chapter is devoted to the future of China as affected by the aims of the Allies.

The appendices contain the Black Dragon Memorandum, The Documents relating to the Twenty-one Demands made by Japan on China, and other official statements and summaries of treaties.

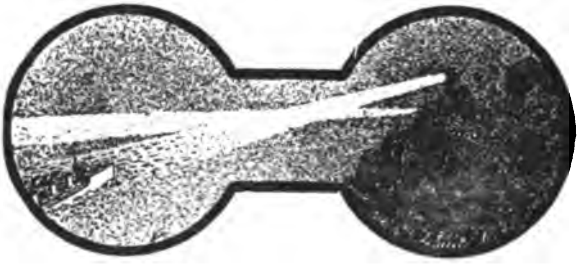
Professor Wheeler understands and sympathizes with the young republic as do all who live for any length of time in that wonderful country. Apropos of Professor Wheeler's predictions it will be interesting to watch events in the Far East provided the United States accepts the League of Nations covenant.

Elementary American History and Government. By James Albert Woodburn Ph. D. and Thomas Francis Moran, Ph. D. After the war edition. N. Y. Longmans, Green and Co. 1919. 5½"x8¼". 568 pp. Pro. il., colored plates.

This school history is planned for use in the grades immediately preceding High School, and the new edition just received "has been reset from beginning to end, and new maps and new illustrations have been added. The main and characteristic features of the text, however, which have been tested by several years of actual use in the classroom, remain unchanged."

Twenty-six pages are devoted to the World War and eleven to a concise index. At the close of each chapter are several "Questions and suggestions" and a list of "References for additional reading," which appear to be very carefully selected. Following these is a "pronouncing list" of difficult words used in the preceding chapter. To those who strained tongue and brain in the early days of the war with such words as "Calais," "Foch," "Joffre" and "Ypres," it is a pleasure to see clear phonetic spellings, and plentiful diacritical marks. Thus is the way made smooth for the student of the present generation.

The book is printed on a good grade of paper, the half-tones and color work are good, the type is clear and of a pleasing size and face, and the book is sewn on two tapes which are fastened to the cover boards, making a very strong and satisfactory binding.



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Journal of the United States Artillery

Vol. 51 No. 4 OCTOBER, 1919 Whole No. 158

THIS ISSUE INCLUDES:

Rotating Bands

The Service of Anti-Aircraft Artillery

Deviation Computing Device for Moving Targets

Practical Interior Ballistics

JOURNAL OF THE UNITED STATES ARTILLERY

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JOURNAL OF THE UNITED STATES ARTILLERY

Published under supervision of the Coast Artillery Training Center Staff, by direction of the Chief of Coast Artillery.

12 numbers per year; volumes begin January and July. Issued on 15th day of each month.

Entered at the Post Office at Fortress Monroe, Va., as second class matter.

Subscription price, per annum:

Domestic	$3.00
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Countries in the postal union	3.50
Single numbers	0.30

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London Agents:
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PRIZE ESSAY COMPETITION

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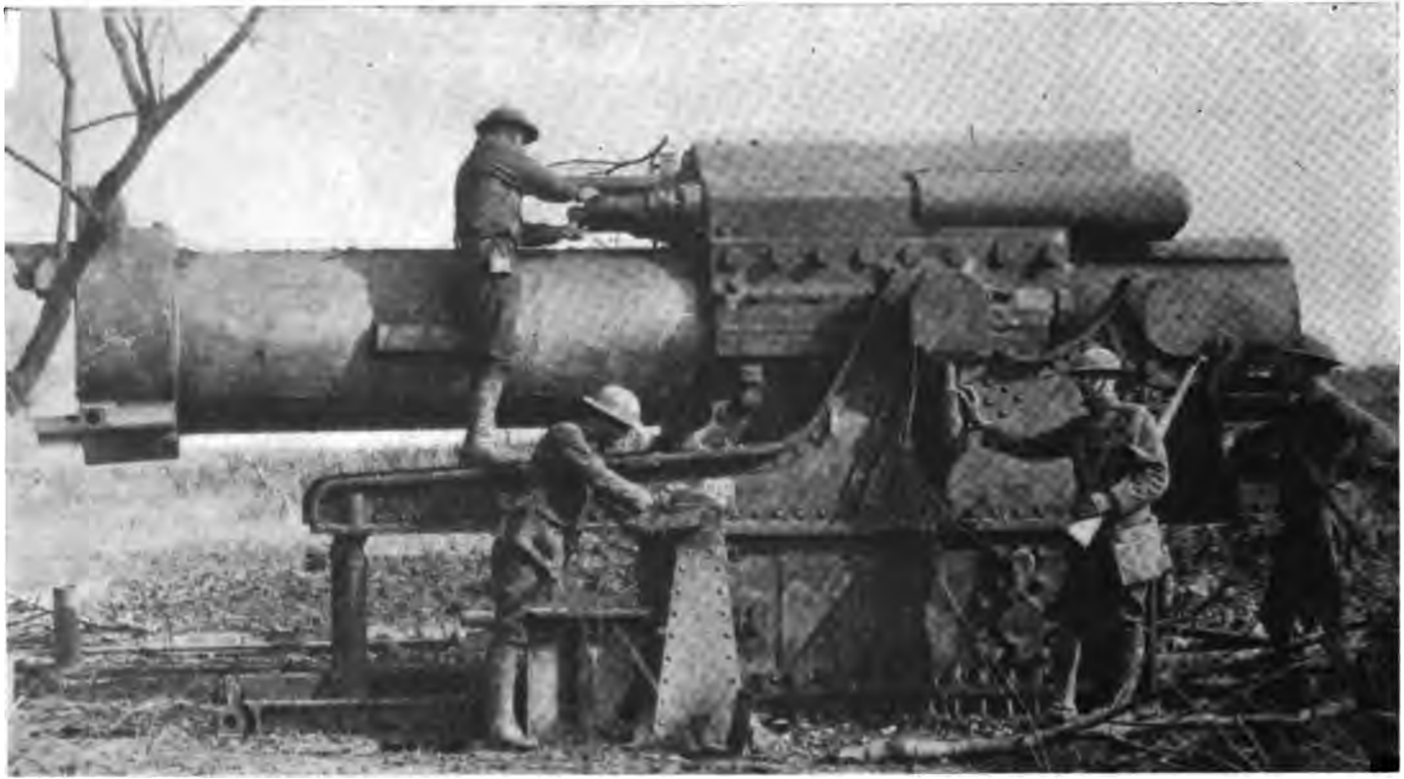

ABANDONED GERMAN 15-INCH GUN

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JOURNAL

OF THE

UNITED STATES ARTILLERY

VOL. 51, No. 4. OCTOBER, 1919 WHOLE No. 158

Rotating Bands

*By Major O Veblen and Lieut. P. L. Alger**

I. EXPERIMENTS

The copper rotating band (or driving band) which encircles the usual modern projectile is a factor of great importance in Artillery fire. Not only does it impart rotation to the projectile but it has large effects upon the accuracy of fire, upon the range obtainable, upon the muzzle velocity, and upon the life of the gun.

The true importance of a careful design of the rotating band was not understood in this country before the war. In consequence, many of our projectiles gave very short ranges and bad dispersions when fired at the elevations required by modern warfare. Experiments made at the Aberdeen Proving Ground and by the A. E. F. led to alterations in some of the existing bands which resulted in enormous improvements both in range and in accuracy.

The results of these firings as well as a study of foreign practice in the design of driving bands have led to the adoption by Ordnance officers of a number of principles governing band design. Many of these ideas are radically different from those heretofore entertained. The purpose of this article is to place before Artillery officers in general an account of these developments. It is very important not only that the advances made should be conserved but also that further studies should be made, for, as will be seen, the experiments thus far carried out cover only a small part of the subject.

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* At the request of the Ordnance Department, this article is published as coming, not from that Department, but as an expression of opinion on the part of the joint authors. Many of the points accentuated in this article are not concurred in by all of the officers responsible for projectile design and consequently the article does not in all respects represent the opinions of the Army Ordnance Department.

The article is divided into two principal parts, the first giving an account of the experiments thus far made, and the second a statement of the ideas at present entertained on the subjects of band design. With regard to the historical sketch, it is well to emphasize the fact that the results are due mainly to excellent co-operation by all concerned, and particularly by the associates of the present writers at the Aberdeen Proving Ground. This renders it difficult, if not impossible, to give proper credit to individuals. Among the officers at the Proving Ground who were concerned were Majors Fullam, and F. P. Lindh, Captain H. B. Taylor, and Lieutenants V. V. Eby, F. E. Fish, D. E. Hill, and B. A. Klein. Suggestions were contributed from Washington by Mr. A. A. Adelman, Major F. R. Moulton, and Captain J. W. Alexander. The work on the 6-inch gun was to a large extent duplicated in France by Captain R. H. Kent.

THE PROBLEM OF DISPERSION

The abnormal dispersion given by a number of our guns, notably the 6-inch and the 4.7-inch, was brought forcibly to the attention of the Ordnance Department early in the war. In particular, range firing of the 4.7-inch gun and howitzer at Sandy Hook in October and November of 1917, and of the 6-inch gun on wheel mount during the winter of 1917-1918 at the same place showed very large variations in range for which no explanation could be found. This was regarded as very surprising in the case of the 6-inch, which was regarded as an especially accurate gun. It had heretofore been fired only at low angles of elevation.

In the Sandy Hook firings, however, so few rounds were fired in each group that the actual existence of a large dispersion was doubted, and much skepticism was expressed as to the reliability of the observations. The real issue was obscured also by the fact that the firings were made with projectiles of experimental types and it was thought that service projectiles would not give these dispersions. The 6-inch shell used were the first projectiles designed with thin walls and it was thought that they might give erratic results because of failure under set-back in the gun. This idea could not be disposed of by recovery firing on account of the lack of facilities at Sandy Hook, in fact the idea seemed to be confirmed by observation of a shell fired into a sand butt which was found to be up-set. In the case of the 4.7-inch the shell used in the firings referred to were modeled after French designs and had different degrees of boat-tailing of the base. To secure complete data for purposes of comparison, the muzzle velocity was measured for each round and this so slowed up the firing that only a few rounds could be fired in any one day. Since the wind aloft was not measured at that time it was thought that the dispersions observed with the 4.7-inch might be due to the variations in wind from day to day.

Although lengthy correspondence and many conversations were held in regard to this question of dispersion, all the explanations suggested were wide of the mark. The favorite hypotheses were that the dispersion was due to erratic powder and hence erratic muzzle velocity, that it was due to instability of the projectile in flight because of its balance or of its stream line shape, and that it was due to the jump of the gun.

The 8-inch Howitzer

The first experiments of the series which led to the explanation and correction of these dispersions were made at Aberdeen with an entirely different gun, namely, an 8-inch Howitzer. A number of 8-inch semi-steel shell which were received for recovery firing had a lip or bead at the rear. This is illustrated in Figure 1 which shows three 8-inch band designs, one with and two without the lip.

These shells were fired for recovery from an 8-inch Howitzer about May 28, 1918. It was observed that the shell varied badly in range and also that the lip of the band partially broke off in flight. Figure 2 shows a photograph of some of these bands. The importance of this observation was noted in the report on the firing, which called attention to the connection between the behavior of the band and the variation in range.

During several weeks, further firings were made with the semi-steel shell and the theory was developed that the lip was forced back while the projectile was in the gun and flared out by the action of the powder gases as the projectile left the gun. In this explanation, the fact that the shell was bevelled or boat-tailed just behind the band, was regarded as an essential element in allowing the powder gases to flare out the fringe of copper at the rear. Up to this time and for some time longer the question of the band was not dissociated from that of the base of the shell.

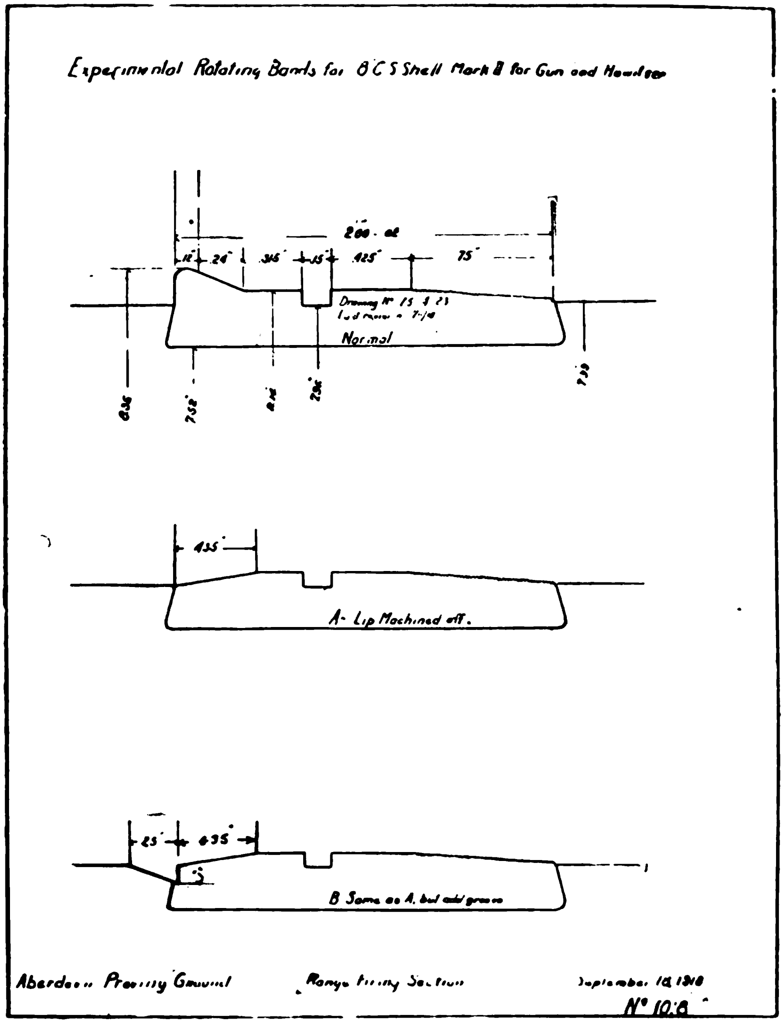

FIG. 1. NORMAL OR LIPPED, AND TWO MODIFIED TYPES OF ROTATING BAND FOR 8-INCH SHELL

2632

The question was also raised whether the observed dispersion could be due to variation in muzzle velocity caused by the shape of the band or by the shape of the base of the shell. The results of comparative velocity firings of 8-inch slugs with various bands showed that no important changes in velocity could be attributed to these causes.

About this time the Range Firing of the 8-inch Howitzer was commenced at Aberdeen. Among the shell piled up for firing, there were several varieties, including some with boat-tailing or. tapered bases and some with lipped band, as well as the normal variety with straight bases and flat bands.*

The opportunity was immediately seized to make comparative range firings with the different types. At first only two or three shell with lipped bands could be found, so that a search was instituted to find more of this type among other 8-inch shell at the Proving Ground. Firings were made with the boat-tailed shell about July 1, which showed that the boat-tailing was the cause of a loss in range and an increase in dispersion.† Firings with the lipped band were delayed by the priority of other firings (for this was a period of great stress) until July 24, when nine shell with lipped band were fired in comparison with nine shell with plain band under identical conditions.

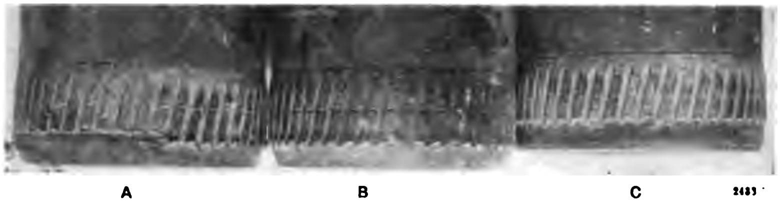

FIG. 2. RECOVERED 8-INCH PROJECTILE FIRED FROM THE 8″ HOWITZER
A. LIPPED BAND, SHOWING FRINGING AND LIP PARTIALLY BROKEN OFF
B. LIPPED BAND, SHOWING FRINGING
C. PLAIN BAND LIKE A. FIG. 1, SHOWING ABSENCE OF FRINGING

This firing proved that the lip alone caused a loss in range of some 700 meters and an increase in dispersion by a ratio of 8 to 1. This result fully confirmed the decision not to use lipped bands in the 8-inch Howitzer. Even now, however, the full importance of the matter was not realized, nor were the results applied to the 6-inch and to the 4.7-inch.

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* This mixture of shell was due to the fact that the first shells designed followed the original English model with the flat band and the straight base. Later it was desired to have a shell which could be used interchangeably in the gun and howitzer. It was thought at this time that a lip was necessary on the shell if it should be fired in the gun. Consequently the gun-howitzer shell had a lip as shown in Figure 1. The boat-tailing of these shell was the result of compliance with manufacturer's requests to simplify manufacture. The consequence was that there were several types of shell put into service, specimens of all of which were present in the lot received for range firing.

† In general boat-tailing at a proper angle increases the range and does not have much effect on dispersion. The boat-tailing of the shells in question was too steep.

The 6-inch Gun

During the first weeks of August range firing of the 6-inch gun was started at Aberdeen and bad dispersion was again observed. On August 14 the Artillery Ammunition Section addressed a letter to Aberdeen saying that the question of dispersion in the 6-inch gun had been cabled about from France and requesting a summary of all the 6-inch and 4.7-inch firings and all the firings with lipped band made in the 8-inch Howitzer to date.

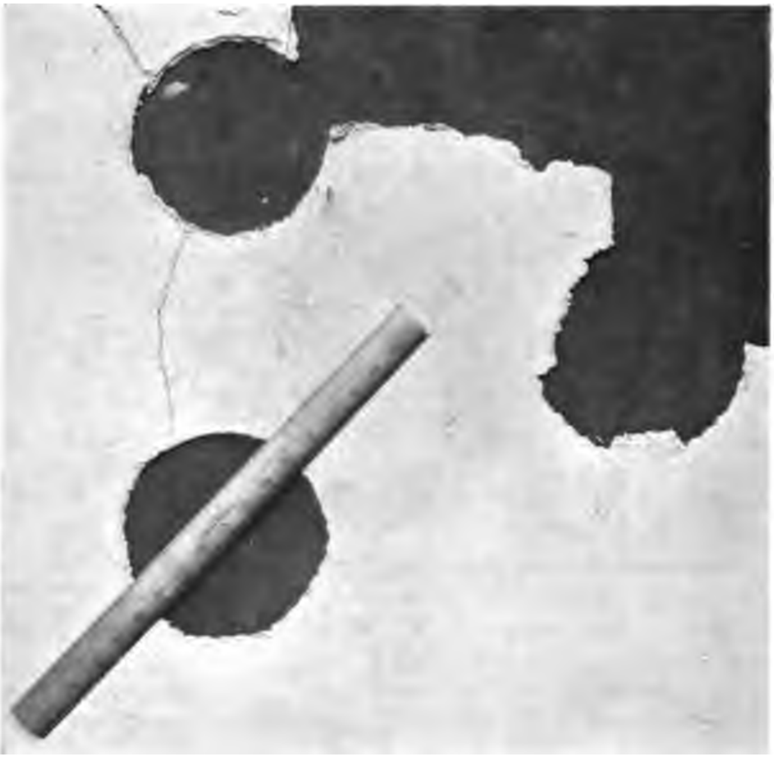
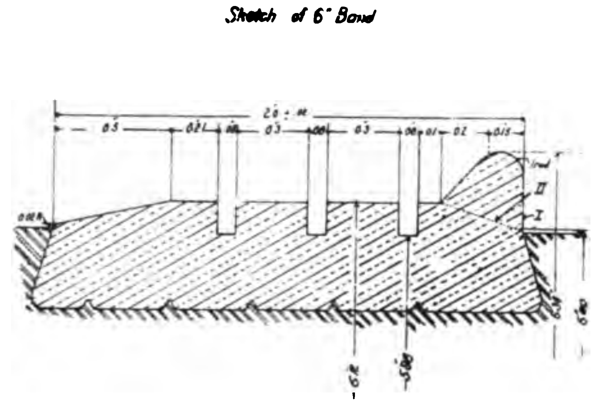


Fig. 3. Cardboard Screen pierced by 6-inch projectiles with lipped bands
Note ragged contour of upper hole and large diameter of lower one

Meanwhile in the course of range firing the 6-inch gun some shots had been fired through a cardboard jump screen which is depicted in Figure 3. The observation that a hole in the screen made by a shell was 6-5/8″ in diameter suggested that the fringing of the band was the cause of the dispersion which had been observed. Accordingly the lip was machined off the bands of several shell in accordance with Figure 4. These shell were fired in comparison with an equal number of normal projectiles at 1950 f.s. velocity on August 19, and 2600 f.s. velocity on August 20.

The results were astonishing to even the most sanguine observer. At 2600 f.s. muzzle velocity and an elevation of 40° a gain in range of over 4500 yards was obtained and the average dispersion was divided by four.



I - This band gives very poor results on account of the lip spreading out in flight

II - To remedy this it is recommended that bands already manufactured be turned down to the dotted line pending the adoption of a new design. Firings made with the modified band have given excellent results.

Aberdeen Proving Ground
Range Firing Section
August 1918

89.

2435

FIG. 4. SKETCH OF 6-INCH LIPPED ROTATING BAND AND MODIFICATION OF IT WHICH WERE USED IN COMPARATIVE RANGE FIRINGS IN AUGUST, 1918

These firings fully established the importance of the effect of fringing and determined what it is that takes place. The lip on the band is dragged back into a fringe of thin copper at the rear of the band when the band enters the rifling. This fringe is flared out into a kind of hoop skirt as the band leaves the muzzle by the action of the powder gases impinging upon it from the rear and by the centrifugal force due to the rotation of the shell. This fringe of copper greatly disturbs the motion of the projectile by increasing the resistance of the air and by changing the line of action of the resultant air forces. This causes a loss of range, and, because of the erratic nature of the fringe, causes great variations in flight from one projectile to another. The photographs in Figures 2 and 5 clearly show the appearance of this fringe on 8-inch and 6-inch shells recovered after firing.

These results were received at first with a certain amount of incredulity. They were confirmed by an extended series of firings from September 3 to 13. The results of these firings are shown in the accompanying table, which gives the muzzle velocity, elevation, mean range, mean deflection, and 50% zones for range and deflection for each group of rounds fired. The complete results are shown in the following table:

RANGE FIRING OF 6-INCH RIFLE FOR COMPARISON OF ROTATING BANDS

DATE	NO. RDS.	GUN MODEL	V(f/s)	E	TYPE OF BAND	AV. R (m)	50% ZONE R	AV. D	50% ZONE D
				° ′				° ′	° ′
Aug. 19	3	1903	1950	40	Lipped	8936	112	4 49	48
	4				Machined	11816	315	2 23	17
Aug. 19	2	1903	1950	45	Lipped	9475	306	4 22	2
	4				Machined	11755	130	2 53	7
Aug. 20	3	1903	2600	40	Lipped	12296	312	3 5	1 17
	4				Machined	16573	71	2 13	10
Aug. 20	4	1903	2600	45	Lipped	12286	324	4 44	1 19
	4				Machined	16821	218	2 28	7
Sept. 3	5	1903	"	28	Lipped	11119	600	2 6	18
	5				Machined	14976	110	1 9	3
Sept. 4	3	"	"	2.45	Lipped	4031	68	0 15	3
	4				Machined	4284	76	0 15	2
Sept. 4	10	"	"	28	Lipped	13000	700	2 20	30
	15				Machined	15271	162	1 31	4
Sept. 5	9	"	"	35	Lipped	12376	1330	3 0	39
	10				Machined	16253	154	1 51	6
Sept. 7	9	"	"	40	Lipped	12894	861	3 40	45
	10				Machined	16578	169	2 40	6
Sept. 10	10	"	"	45	Lipped	12886	895	1 45	37
	10				Machined	16880	162	2 4	8
Sept. 11	10	1900	"	31	Lipped	14029	481	1 58	22
	10				Grooved	15589	233	2 11	5
	10				Machined	15454	88	2 12	5
Sept. 11	10	1903	"	35	Grooved	16195	174	2 7	20
	10				Machined	16106	130	2 4	16
Sept. 13	5	"	"	6	Machined	7107	59	0 22	4
	10	"	"	12	Machined	10179	46	0 39	2
Sept. 14	5	"	"	18	Machined	12252	47	1 2	6
	10	"	"	24	Machined	13995	108	1 6	2

"Machined" or plain bands are like type A, Fig. 1 being obtained by machining off the lip from bands like normal type, Fig. 1 "grooved" bands are like type B, Fig. 1.

Throughout the firings all precautions were taken to insure uniform conditions for the two types of projectile and to obtain accurate and complete observations.

Examination of the records of these firings shows that the plain bands give very accurate ranges and deflections but that the shell with lipped bands scatter themselves over an area sometimes 3500 yards in length by 2 or 3 degrees in width. The greater proportion of the latter shell group themselves at long range but a few always straggle along at varying distances behind. Also the mean range and deflection of the lipped shell vary from day to day very erratically as do the magnitudes of their dispersions.

A very interesting point is that the drift of the shell with lipped band is invariably greater than that of the shells with plain bands. This indicates that the average angle between the axis of the shell and the tangent to the trajectory is greater when the lip is present than when it is absent. Evidently the whole system of forces to which the shell is subject is altered by the presence of the fringe due to the lip.

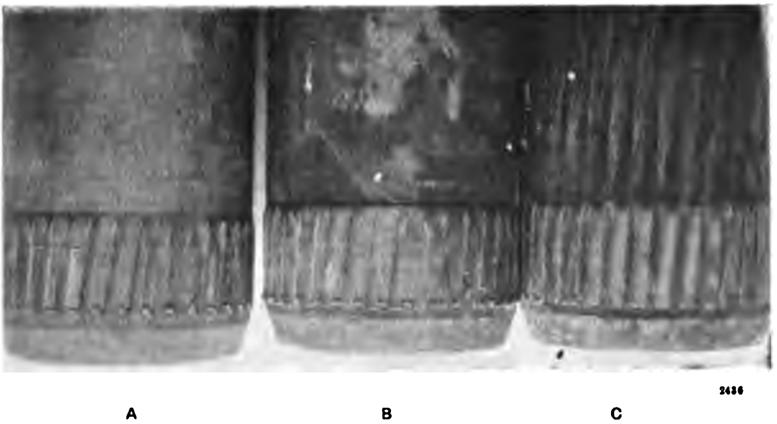


Fig. 5. 6-inch Mark II shell recovered after firing
A. Shell with lipped band, showing fringing
B. Shell with lipped band, showing fringing
C. Non heat treated shell which upset in the bore. Lipped band on this shell did not fringe

Developments Elsewhere Than at Aberdeen

This work at Aberdeen was closely paralleled in France by Capt. R. H. Kent, Ordnance Dept., who from a study of the results of the Aberdeen firings in the 8-inch Howitzer reasoned out a solution of the difficulties in regard to the 6-inch gun. After some difficulty in convincing other officers of the desirability of the test, he had the lips machined off from the bands of some 6-inch shells and fired these projectiles in comparison with normal ones. The results were the same as those obtained at Aberdeen. The cablegram giving the Aberdeen results was received by the A. E. F. simultaneously with the completion of Captain Kent's experiments.

The Naval Proving Ground was also on the track of the rotating band in the summer of 1918. The Naval 3-inch and 4-inch shell have bands of the plain Vavasseur type quite similar to the Army 4.7-inch band shown in Figure 6. Comparative firings were made at Indian Head between 3-inch shell with normal bands and others with bands of reduced diameter which showed large gains in favor of the latter in range and dispersion. Confirmatory firings were made with 4-inch shells on August 7 which gave the same results. The explanation of the phenomena was not discovered there as soon as at Aberdeen, perhaps chiefly because of the lack of facilities at Indian Head for recovery of fired projectiles.

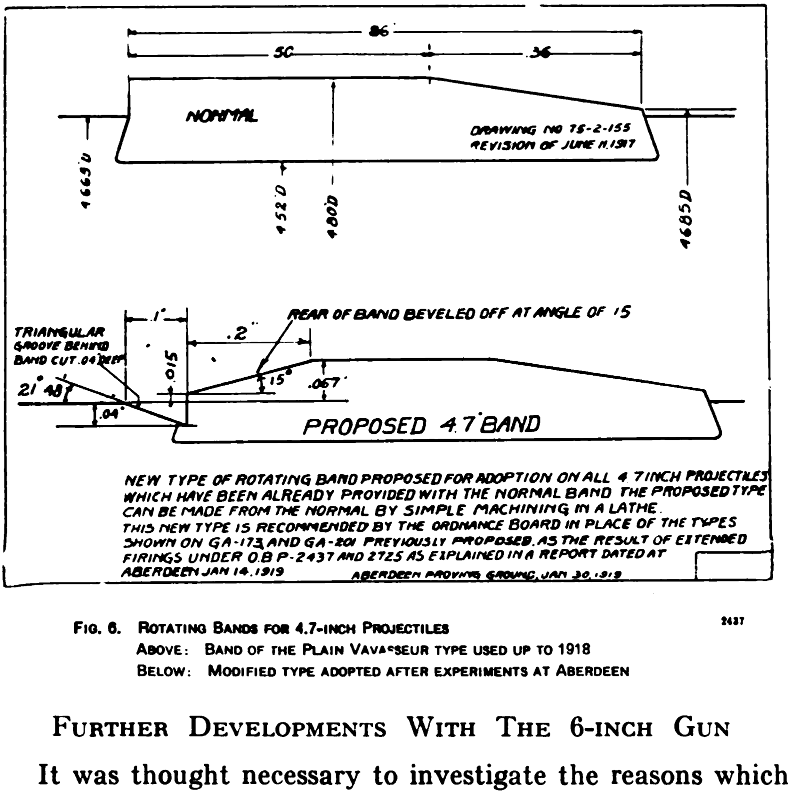

.86
.50
.36
NORMAL
DRAWING NO 75-2-155
REVISION OF JUNE 11.1917
4.665 D
4.52 D
4.80 D
4.685 D
.1"
.2"
REAR OF BAND BEVELED OFF AT ANGLE OF 15
TRIANGULAR
GROOVE BEHIND
BAND CUT .04" DEEP
.015
21° 48'
15°
.067"
.04"
PROPOSED 4.7" BAND
NEW TYPE OF ROTATING BAND PROPOSED FOR ADOPTION ON ALL 4.7 INCH PROJECTILES
WHICH HAVE BEEN ALREADY PROVIDED WITH THE NORMAL BAND THE PROPOSED TYPE
CAN BE MADE FROM THE NORMAL BY SIMPLE MACHINING IN A LATHE.
THIS NEW TYPE IS RECOMMENDED BY THE ORDNANCE BOARD IN PLACE OF THE TYPES
SHOWN ON GA-173 AND GA-201 PREVIOUSLY PROPOSED. AS THE RESULT OF EXTENDED
FIRINGS UNDER O.B P-2437 AND 2725 AS EXPLAINED IN A REPORT DATED AT
ABERDEEN JAN 14.1919
ABERDEEN PROVING GROUND, JAN 30.1919
2437

FIG. 6. ROTATING BANDS FOR 4.7-INCH PROJECTILES
ABOVE: BAND OF THE PLAIN VAVASSEUR TYPE USED UP TO 1918
BELOW: MODIFIED TYPE ADOPTED AFTER EXPERIMENTS AT ABERDEEN

FURTHER DEVELOPMENTS WITH THE 6-INCH GUN

It was thought necessary to investigate the reasons which led to the original adoption of the lip before its removal could be approved. One of these reasons was to preserve uniform seating in old and new guns, so as to avoid a loss in muzzle velocity as the gun eroded. However, comparative firings made in an old gun (indicated in the table of results as the Model 1900 gun) also showed substantial advantages both in range and in dispersion for the bands without the lip. It was found that the difference in seating between the lipped and plain band in the old gun was only about ¼″, which would cause not more than 10 f.s. difference in velocity. The difference in range and dispersion between the lipped and plain bands, although substantial, was less in the old gun than in the new one. It is believed that this is because both bands partially stripped in the old gun. This stripping, which occurs as a result of erosion, removes a portion of the excess copper and consequently reduces the fringing effect.

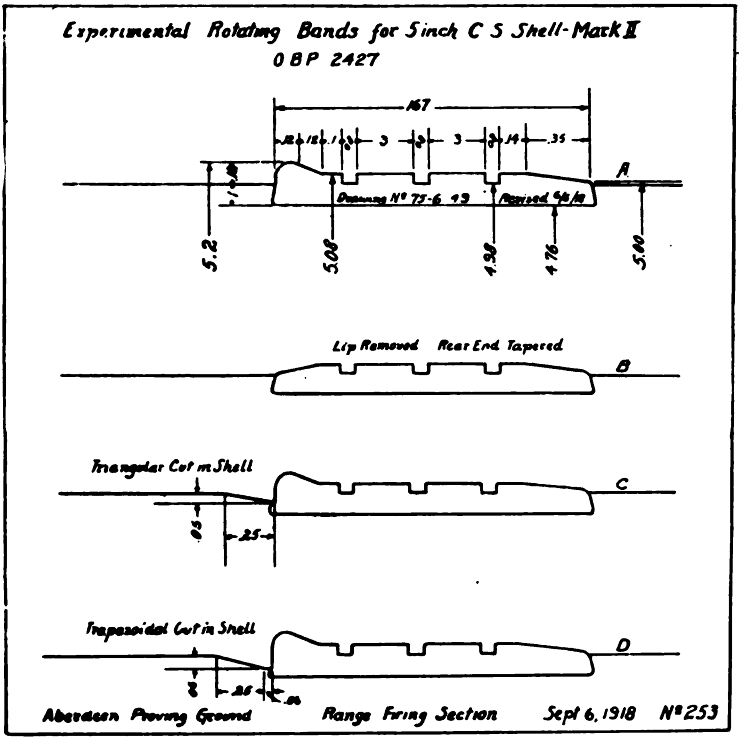


FIG. 7. TYPES OF ROTATING BANDS FOR 5-INCH SHELL 2688

At this time the opinion was strongly held in some quarters that the lip served an important purpose as a gas check, and consequently ought to be preserved in order to prevent severe erosion of the gun. As indicated below the writers do not concur in this opinion. Nevertheless it was suggested by one of them that the lip could be retained if a groove were cut in the steel behind the band in the manner shown at "C" in Figure 7, thus providing a place into which the copper could be forced without being squeezed so thin as to cause fringing. A few firings made with projectiles of this type showed as good ranges and dispersion as with the plain type of band.

A combination similar to that shown at "B" in Figure 1 gave equivalent results. It was finally decided that under existing war conditions the simplest solution of the problem was the best. Consequently it was decided to remove the lip from all 6-inch bands in the manner indicated at II in Figure 4.

The plain band for the 6-inch shell has proved thoroughly satisfactory in practice. Nevertheless another type of 6-inch band has been designed by the Artillery Ammunition Section which preserves the lip and yet avoids fringing. The lip on this band is set well forward and there is a deep annular recess in the band behind it to receive the excess copper. Firings have shown that this band gives the same results in range and accuracy as the plain band. There is reason to think, however, as explained below, that this band will cause more erosion than the plain one.

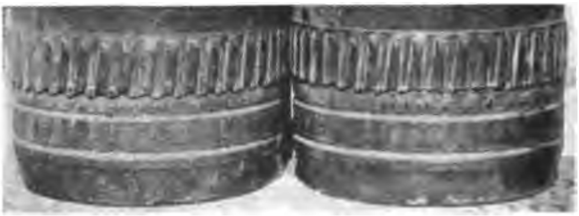


FIG. 8. RECOVERED 4.7-INCH SHELL WITH NORMAL BANDS, SHOWING SLIGHT FRINGING

THE 4.7, 8-INCH AND OTHER CALIBERS

Another step in advance was taken when it was shown that the bad dispersion of the 4.7-inch gun was due to the band. This band, which is of the form shown in Figure 6, had no lip, but nevertheless recovered shell showed a small amount of fringing, as exhibited in Figure 8. The exact way to remedy the difficulties due to the band being in doubt, four types of modified bands were tried in comparison with normal in the first experimental firings, held on August 28.

It was found that every modified band performed better than the normal, over 1000 meters gain in range being secured by the best type. Consequently a series of further firings was carried out in which many combinations of types were tried. It was found that by removing some copper and providing a recess for the rest to flow into the difficulties could be overcome, and the type of band shown in Figure 6 was finally adopted. One of the considerations which led to the adoption of this band was the necessity of adjusting the rear bevel in such a way as to prevent the cartridge case from over-riding the band during the assembly of a complete round.

Officers at Aberdeen were anxious to try bands without the lip in the 8-inch gun, but it was not until late September that a gun was available for this purpose at Aberdeen. The proposed firings were not made earlier at Sandy Hook because when a shell with the lip removed from the band was inserted in the chamber of the 8-inch gun, it was possible to "see daylight around the shell." The firings were actually made on a Sunday, September 22, because of the pressure of other work on the 8-inch gun which was given priority.

They showed a gain of 2000 meters in range and a decrease of dispersion by a factor of 6 or more. These firings compared bands of the three types shown in Figure 1. The appearance of recovered shell of these types is exhibited in Figure 9. Further firings made later confirmed these results. Experience in firing several hundred rounds of shell with plain bands in the 8-inch gun tends to confirm the opinion expressed below that it is not necessary to have a lip on the band to serve as a gas check, and that to remove it does not cause severe erosion.

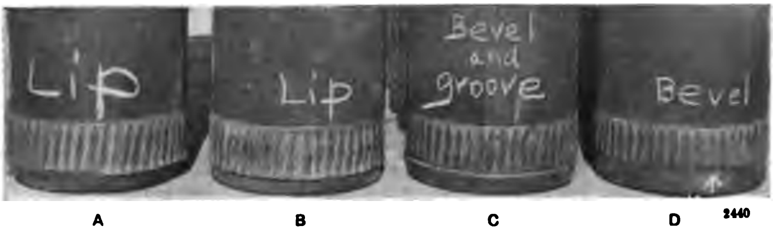


FIG. 9. 8-INCH SHELL RECOVERED AFTER FIRING FROM THE GUN
A. AND B. SHELLS WITH LIPPED BAND AS SHOWN ON FIG. 1
C. SHELL WITH BAND LIKE TYPE B, FIG. 1
D. SHELL WITH BAND LIKE TYPE A, FIG. 1

A band with the lip set forward and a recess to receive the excess copper has been designed for the 8-inch gun. As in the case of the 6-inch it gives results similar to those obtained with a plain band, in so far as range and accuracy are concerned. It is our opinion that this band will give greater erosion than a plain band.

Comparative Range Firings in the 5-inch gun gave similar though less striking results. The lip on the original band was smaller in proportion than that of the 6-inch, and it consequently had less harmful effect. The various types of bands tried out in these firings are shown in Figure 7. The hole made by a normal shell fired thru a cardboard screen showed the characteristic scalloped edges which indicate fringing (See figure 10.)

On the arrival at Aberdeen of a 14-inch Naval Gun, on Railroad Mount, of the type used in the A. E. F., range firings were conducted with a new type of shell and the opportunity was presented to make comparative firings with shell provided with modified bands. On account of the very small number of shell available and the necessity for preparing a range table from the results of the firings, no definite determination of the dispersion due to the band could be made. However, enough firings were made to show that the lip caused an appreciable decrease in range, so that it was decided to remove the lip as in the other cases.

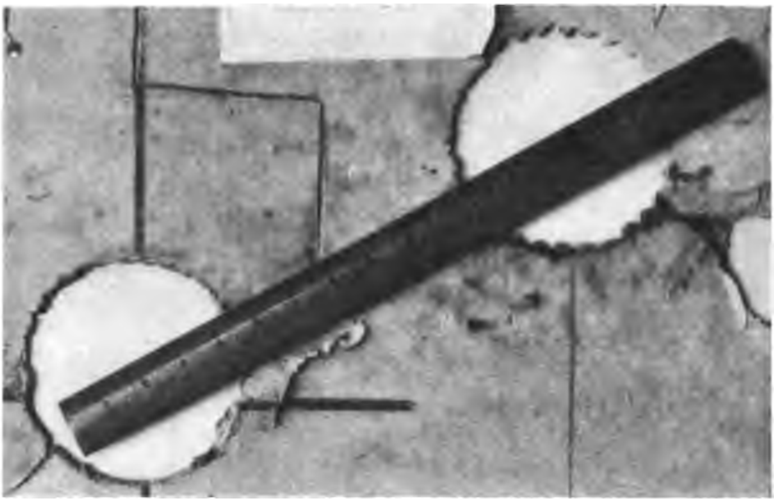


Fig. 10. Cardboard Screen pierced by 5-inch shell with lipped Rotating Bands 2441

Experiments with modified bands have also been made in the 75 MM Gun, 155 MM Howitzer, 12-inch Mortar, 240 MM Howitzer, and 16-inch Howitzer, but these do not show any appreciable gains resulting from alterations of the band. The reason for this lack of improvement in the cases of the first two guns is that the bands experimented with were of French design and already embodied careful thought with the intent of avoiding fringing. The beautifully engraved band of the French 155 MM Howitzer shell forms a striking contrast with the 6-inch band beside it in Figure 11. For the two larger guns, no improvements were observed on account of the relatively small effect of fringing in the case of a heavy shell fired at low velocity, and on account of the relatively small sizes of the lips on the 12-inch and 16-inch shells. It is felt that under particular conditions, fringing might be extensive, enough, even with these projectiles, to cause determental effects, and that in any case, there is a slight fringing which has some bad effects, though they are small. Examination of recovered 240 MM Howitzer shell has shown that the device of merely reducing the diameter behind the lip to receive the excess copper is not satisfactory, as fringing occurred despite the thickness of the extruded copper.

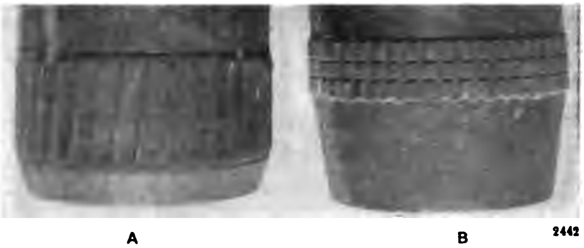


FIG. 11. RECOVERED SHELL

A. 6-INCH SHELL FIRED FROM GUN WITH INCREASING TWIST OF RIFLING SHOWING BADLY SCORED BAND WITH LARGE OVERHANG AT THE REAR

B. 155 MM. SHELL FIRED FROM A HOWITZER WITH UNIFORM TWIST OF RIFLING SHOWING BEAUTIFULLY ENGRAVED BAND

PART II: PRINCIPLES OF DESIGN

In the experiments which are described above the main effort has been confined to correcting faults in already existing matériel. The changes made in bands were all of a sort which could be accomplished by putting the projectile in a lathe and turning off small parings of copper or steel. In most cases, the band as originally designed, had too much copper and in every case a substantial improvement was gained by merely removing some of it.

Let us now consider some of the requirements which a properly designed band must satisfy. These requirements are inextricably linked with the characteristics of the rifling of the gun, so that consideration will also be given to the elements entering into the design of rifling. We shall first set down the principal requirements which a band should satisfy, then discuss various proposals having to do with the design of bands and rifling in such ways as to satisfy these requirements, and finally arrive at conclusions leading to definite recommendations in regard to design. The principal requirements which a band should satisfy are: that it should have sufficient strength to impart rotation to the shell with certainty, that it should be so shaped as to be neatly engraved by the rifling, that it should not be the cause of additional erosion of the gun and that it should be serviceable in both old and new guns. These requirements and other less important ones are discussed, approximately in the order of their importance, in the following paragraphs.

(a) EFFICIENCY AS A ROTATING DEVICE

The primary purpose of a rotating band, is to engage with the rifling of the gun barrel so as to impart to the projectile exactly the amount of rotation provided for by the pitch of the rifling. This means that the rifling lands must not slip over the copper of the band and must not shear it. To avoid stripping the bearing surface between the band and the rifling should be large, so that the pressure on each part of the copper may be small. In certain cases copper rotating bands are abandoned in favor of stronger rotating devices. High power guns such as the long range guns with which the Germans bombarded Paris require the use of a new device to secure rotation for the projectile. The device which has been adopted is that of introducing rifling grooves cut in the steel surface of the projectile. It is also impossible to use copper bands in lower power guns when projectiles of greater than a certain weight are used, because in this event the pitch of rifling must be very steep and the consequent stress on the band becomes too great.

(b) NEAT ENGRAVING

When the projectile leaves the gun the rotating band necessarily constitutes a protuberance on its surface, and as such impedes the flight of the projectile to a greater or less extent. The bad effects of a design which allows this protuberance to be large or irregular are well illustrated by the firings described above. It is therefore important to design the band so that when it has passed through the gun it will have been carved out or *engraved* by the rifling as neatly as possible.

(c) EFFECT OF BAND ON EROSION

The third condition which must be satisfied in the design of rotating bands is that they shall cause as little wear or erosion of the gun as possible. On the causes of erosion there are wide differences of opinion, principally because the amount of direct experimental data on the subject is very limited. It is difficult to obtain experiments which will distinguish between the possible causes of erosion.

The prevailing opinion among the best foreign experts who have been consulted appears to be that one of the principal causes of erosion is the direct wear of the steel of the gun by the friction of the copper band. The fact that copper is very soft is not considered a substantial argument against this view, as even butter would cause wear if forced through a gun at sufficiently high velocity. Any wear due to this cause would be greatest at the points where the copper is being engraved or where the relative velocity between the steel and copper surfaces is the greatest. Consequently the character of the normal type of erosion, which is greatest at the origin of rifling and next greatest at the muzzle, in some degree substantiates this view. This view is also supported by various experiments in which it has been found that bands which have been hardened alloying the copper with other metals have considerably increased the wear of the gun and that the use of bands which have an increased diameter has also resulted in more rapid wearing out of guns.

Another important cause of erosion is the action of the hot gases on the steel surface of the bore. This erosion is facilitated by the rapid expansion and contraction of the gun which severely strain the metal and render it subject to cracking. Any roughening of the surface of the steel due to these causes will accelerate the erosion due to the friction of the band as slight projections will readily be carried away. Erosion caused by gases will be greater as the temperature of the steel is higher and as the velocity of the gases is greater. There have been two methods of explaining this erosion due to the gases.

According to one point of view, it is considered that the gases cause erosion by their scouring action on the already heated bore of the gun after the passage of the projectile.

It is considered that the time element involved in heating the steel is very important and that the great erosion observed at the origin of rifling is largely due to the fact that a projectile spends about half the time of its travel in the bore in moving a distance equal to one caliber so that this first caliber's length of the rifling is subject to heating for twice the length of time that the rest of the bore is. This method of explaining the gas erosion is accepted by the present writers.

The other opinion is that the gases escaping past the band during the motion of the projectile down the bore have a very high velocity and therefore cause severe erosion. The lip on the rotating band has been considered desirable as a means of reducing this "windage," and arguments in favor of an increasing twist of rifling have been adduced on similar grounds. Against this view it must be said that the gas which escapes past the band is very much cooled in so doing, that the steel subject to its action is cold, that the time during which the action can take place is extremely small, and that the amount of gas which actually escapes is small. Experiments have been made abroad by firing a projectile which has a hole bored all the way through its middle along the axis. It was found that there was no evidence of the powder gases having passed more than a couple of inches down this hole. In other words little if any of the gas got through the hole ahead of the projectile.

It is now the opinion of most of the authorities whom we have consulted that although the effect of the hot powder gas behind the projectile is great the effect of windage is small.*

This point of view implies that the erosion by action of the powder gases is but little affected by the design of the band. On the other hand the character of the band has a large effect on the wear of the gun by the copper.

The best conclusion which it seems possible to draw at present, in the absence of further experimental data, is that the design of rotating bands should be such as to eliminate as much as possible of the frictional wear due to the relative motion of the copper and steel surfaces. This is to be accomplished by reducing the amount of copper in the band to a minimum. This policy also conduces to ease and economy in manufacture.

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*This view is, in substance, that advanced by Prof. P. R. Alger, U.S.N., in articles in the Naval Institute Proceedings for September and December, 1910.

(d) ADAPTATION TO OLD AND NEW GUNS

It is far from obvious that a band which gives good results in a new gun will do the same in a gun which has been considerably worn. It has therefore been the practice in the design of rotating bands to attempt to strike a balance between a design which is suitable for a new gun and one which is suitable for an old gun. But it is a question how far one ought to go in this direction. For example: is it better to design a band which gives mediocre results for a life of 500 rounds or to design one which shall give first class results for a life of 400 rounds but poor ones during the successive 100 rounds?

(e) SEATING

It has generally been required that a rotating band shall serve as a device to insure that the projectile shall always go to the same position in the powder chamber in order to secure a constant density of loading. It is not necessarily very important that the seating should remain unchanged during all the life of the gun but it is important that the seating should not vary much from one round to a successive round. It is not obvious, as has usually been assumed in the past, that uniformity of seating should be taken care of by means of the rotating band. Other devices for this purpose will be suggested below.

(f) HOLDING THE PROJECTILE IN PLACE

The rotating band has often been used as a device to prevent the projectile from dropping back into the powder chamber when the gun is elevated in high angle fire. It is, of course, important that this result should be secured but it is by no means obvious that it should be done by means of the rotating band.

(g) SEALING

The rotating band has been expected to serve as a gas check, that is, to seal the gun barrel in such a way that the powder gases cannot escape past the projectile. For reasons which were pointed out above it is believed that windage is not an important cause of erosion. It was shown in connection with the 8-inch gun firings referred to above that windage causes very little loss of velocity. Hence it seems safe to assume that the gas check function of a rotating band is unimportant.

(h) BALLOTTING

By ballotting is meant the moving about of a projectile within the bore of the gun. Some consideration has been given to designing and placing the bands in such a way as to reduce ballotting to a minimum. Just how much actual ballotting takes place is questionable. The only evidence available is furnished by the rifling marks on recovered projectiles. In general these marks are found only on one side of the projectile.

(i) STABILITY OF PROJECTILE ON LEAVING THE GUN

The position and the design of the band have an effect on the manner in which the projectile leaves the gun and it may be possible by proper care in the design and location of the band to cause the projectile to leave the gun more steadily and with less variation from round to round, thus improving both range and accuracy.

RELATED QUESTIONS

Other questions which intimately concern the band design are the position of the band on the shell and the pitch of the rifling. The best position of the rotating band has not been well determined as yet. To minimize the disturbing effect of the powder blast on the projectile the band should probably be placed toward the rear. But to minimize bad effects due to any eccentricity of the projectile the band should be placed near the center of gravity.

The position of the band has an influence on the flight of the projectile because the band is a protuberance on the shell and consequently sets up a disturbance in the air with which it comes in contact. Varying the position of the band therefore varies the system of forces to which the shell is subject in its flight. From this point of view it would probably be desirable to place the band far forward.

Since the band groove weakens the walls of the shell it has been customary to place the bands of large caliber projectiles very close to the base where the walls are thickest. In medium calibers, it has lately become the practice to place the band far enough forward to leave space for a suitable boat-tailing, as the latter has been found to be desirable. Such experiments as have been made indicate considerable gains to be obtainable by moving the band forward without other change.

The choice of the final pitch of the rifling depends upon the length of the shell and the muzzle velocity, as it must be so chosen as to make the shell stable in its early flight and yet should not be any steeper than necessary for this purpose. A too steep rifling is likely to make the shell come down sideways in the latter part of its flight and in any case the steeper the rifling the greater the stress on the band and consequently the shorter the life of the gun.

Experiments on Deformation of Bands

There have been described in the foregoing paragraphs the principal elements which must be considered in the design of the rotating band. In order to obtain definite ideas in regard to the manner of deformation of bands when fired in guns of varying ages, a large number of recovered projectiles were examined and a few bands were deformed mechanically by inserting them in guns and twisting them with leverage applied by hand.

Examination of rotating bands on 75 MM projectiles recovered after firing showed that they were frequently very interestingly deformed in the gun and that stripping nearly always occurred when projectiles were fired at 12 per cent excess pressure. The series of four bands shown in Figures 12 to 15 presents the appearance of bands fired with excess charge from guns of different ages. It is seen that the first band is neatly engraved except for scorings on the forward non-driving edges of the ridges. The second band shows a scoring extending across the entire width of the band. The third shows two distinct ridges; the principal one, having a remarkable semi-circular contour; and the other being a mere raised fin of copper. The fourth band is completely stripped and shows very bad fringing at the rear.

It was at first thought that the curved engraving of the bands might be explained by erosion due to the hot gases escaping past the band in its passage down the bore, but it is now believed that the deformation of the band is a purely mechanical action and that the gases have no part in producing the observed markings. This belief is largely due to the results of the experiments which are explained and illustrated in Figure 16. Several 75 MM shell were recovered with their rotating bands neatly engraved as in Figure 13, and holes were bored diameterically thru the shell bodies. The shell were then inserted in the muzzle of a 75 MM gun

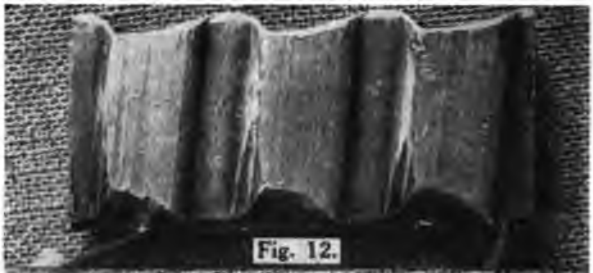
Fig. 12.

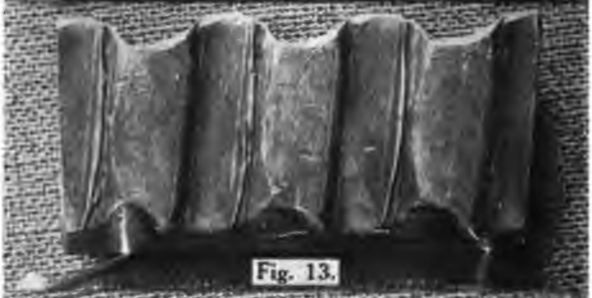
Fig. 13.

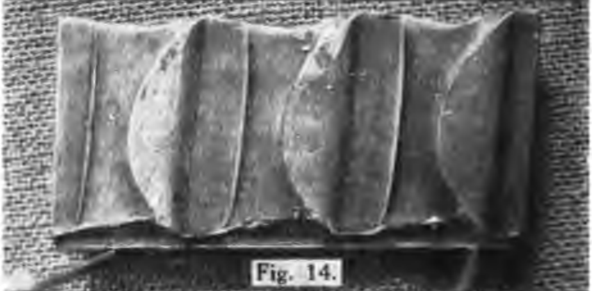
Fig. 14.

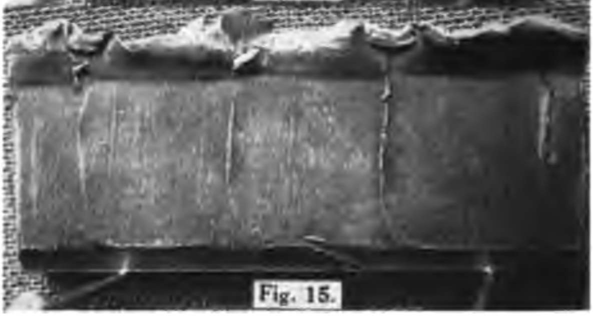
Fig. 15.

2443

Fig. 12. Section of band from recovered 75 mm. shell fired from a new gun. Note unsymmetrical engraving due to variable twist of rifling and scorings on the forward covers of ridges

Fig. 13. Section of 75 mm. Band from recovered 75 mm. shell fired from a slightly worn gun

Fig. 14. Recovered 75 mm. Band fired from worn gun

Fig. 15. Recovered 75 mm. Band fired from a very worn gun

and forcibly twisted by means of crowbars passing through the holes in the shell body. The force required to twist the shell was so great that it was necessary to chip off all but six of the ridges from the bands, before suitable control over the twisting could be exercised by hand. The shell were twisted thru different angular distances to simulate the action of the band being sheared or stripped in firing. It was found that the ridges of copper behaved somewhat like waves, as instead of definitely giving way under an excessive torque they slipped circumferentially, the copper tailing off at the front and rear edges of the band during the motion. The ridges thus developed a semi-circular front very similar to, though less pronounced than that observed on fired bands such as those shown in Figure 14. Since the width of a land and groove together is less than ten mm, in the case of the 75 MM gun, while some of the bands were turned thru 11 or more mm without being absolutely stripped, it is evident that a fired band will slip thru a considerable angle before definitely stripping.

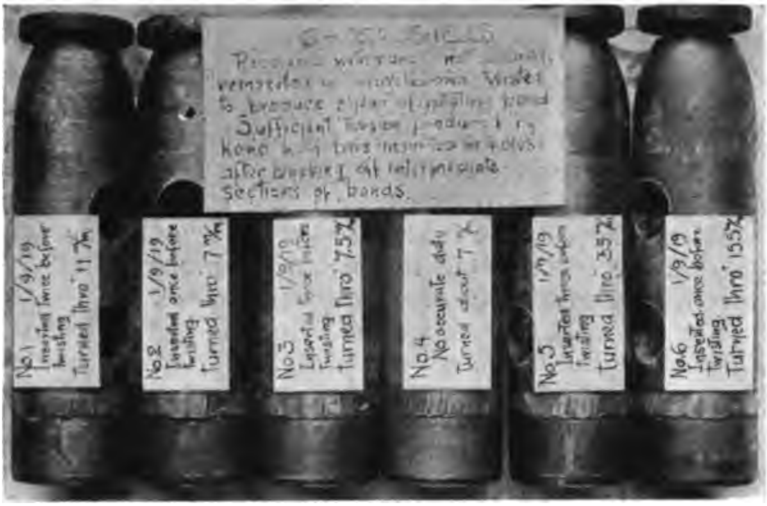
No.1 1/9/19 Inserted twice before twisting Turned thro' 11 %m
No.2 1/9/19 Inserted once before twisting Turned thro' 7 %m
No.3 1/9/19 Inserted twice before twisting Turned thro' 7.5%
No.4 No accurate data Turned about 7 %
No.5 1/9/19 Inserted twice before twisting Turned thro' 3.5%
No.6 1/9/19 Inserted once before twisting Turned thro' 15.5%
sections of bands.
2444

FIG. 16. THE RESULT OF EXPERIMENTS IN WHICH 75 MM. BANDS WERE SHEARED ARTIFICALLY TO COMPARE WITH BANDS RECOVERED AFTER FIRING

In view of the appearance of the bands recovered after firing and in view of the experiments described in the foregoing paragraph, it is believed that the phenomena of deformation of the band in firing in a worn gun may be briefly explained as follows:—On the explosion of the powder charge the band is forced into the rifling, and thereby a torque is applied tending to rotate the shell. Since the rifling at the start is badly worn, the band probably does not fill up the grooves, and the lands of the gun only bite into the bands to a very small depth. Consequently the bearing surface is insufficient, and each land of the rifling starts a small chip of copper which curls over into the space between the top of the band and the bottom of the grooves of the rifling. The action is analogous to that of a blunt lathe tool. As the shell moves further forward into the rifling, the diameter of the latter becomes less on account of the decreased erosion, and each chip of copper becomes deeper. Soon the resistance of the copper becomes great enough to stop the slipping and after this the rotation of the shell proceeds in exact accordance with the slope of the rifling. As the band moves still further forward, the diameter of the gun continues to contract, and the copper is subjected to a large radial compression, which pushes up the secondary ridge shown on Figure 14 and which squeezes the accumulated turnings of copper down into the pronounced semi-circular shape above described.

The fact that slipping frequently occurs in the early part of the motion even though the shell may leave the gun with the normal amount of rotation has a very important bearing on the question of increasing versus uniform twist of rifling. The slipping causes an automatic smoothing out of the curve of stress on the band plotted against travel of the projectile which is of an exactly similar nature to that which the use of an increasing twist of rifling is intended to produce. Consequently it may be questioned whether the use of this form of rifling really gives any advantage in the reduction of stress on the band. It would be interesting to investigate theoretically the change in the rotational forces caused by the band slippage, knowing that in the case of the 75 MM, at least, the band may slip through some 25 degrees, or about 1/20 of the entire angular motion in the gun, without entirely giving way.

The phenomena of band slipping were particularly well illustrated by the 75 MM bands, since the field guns of this caliber now in use have a depth of rifling of only .02 inches; and have, consequently, a tendency to strip under excessive pressures. In addition to its shallowness this rifling has another objectionable feature, in that the fillets at the base of each land are of large radius so that over-riding of the ridges on the bands by the lands of the gun is facilitated. In the case of the 4.7-inch gun, which has rifling .04 inches deep, stripping of the band is a very rare occurrence. The rifling of American 75 MM guns has been made in accordance with the practical aspects of design or to be interchangeable with foreign matériel, and it is for these reasons that the present form of rifling was adopted. The depth of rifling in a fixed ammunition gun is definitely limited by the thickness of the mouth of the cartridge case, since the case will be swelled and cracked by the powder pressure if the external diameter of the cartridge mouth is less than that of the band. Consequently the disadvantages of a heavy cartridge case go with the advantages of a deep rifling.

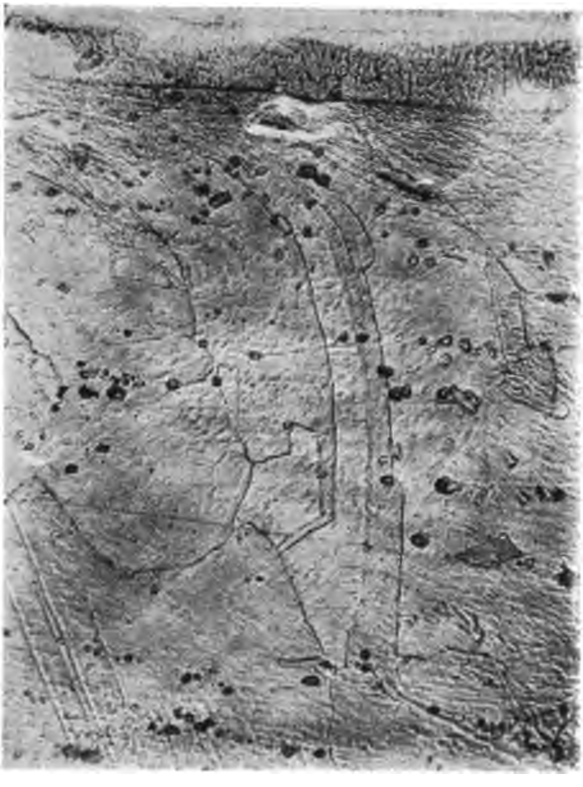

FIG. 17. LONGITUDINAL SECTION OF 75 MM. BAND MAGNIFIED 500 TIMES 2445

MICRO PHOTOGRAPH OF SECTION OF 75 MM. BAND SECTION MADE THROUGH A RIDGE ON A BAND FIRED FROM A NEW GUN BY A PLANE PASSING THROUGH THE AXIS OF THE SHELL. TAKEN FEBRUARY 1919. BUREAU OF STANDARDS THE SURFACE OF THE COPPER WAS PROTECTED BY A LAYER OF ELECTROLYTIC COPPER BEFORE SECTIONING. (x)

In order to throw new light on the deformation of bands, the aid of the Bureau of Standards was enlisted in securing microphotographs of cross sections of rotating bands recovered after firing. These photographs did not lead to as conclusive results as hoped, but they brought out two interesting features. In Figure 17 there is shown a longitudinal section of a 75 MM band which was recovered in good condition after firing from a new gun. The photograph clearly shows that a thin layer of copper on the top of the ridges was severely worked and dragged rearwards by the passage of the band through the gun, but that the disturbance reached only a very shallow depth. In Figure 18 there is shown a cross section of another 75 MM band which was partially stripped in firing. This photograph shows the curling edge of copper at the non-driving edge of the ridges on a partially stripped band.

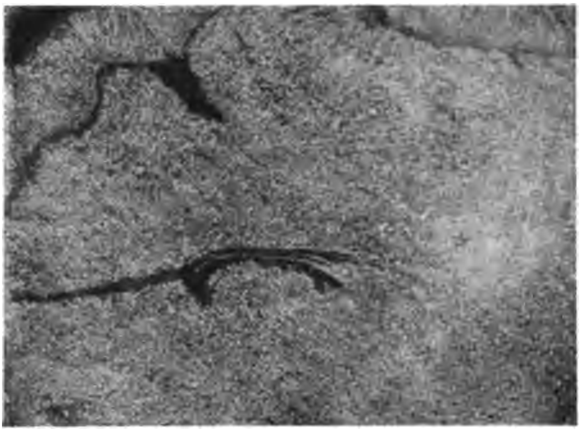

Fig. 18. Cross Section of 75 mm. Band, magnified 100 times 2446

Micro Photograph of section of 75 mm. Band section made through a ridge on a band fired from an old gun by a plane perpendicular to the axis of a shell. Taken February 1919. Bureau of Standards Photograph taken looking toward the base of the shell. The surface of the band was protected by a layer of electrolytic copper before sectioning. (x)

RECOMMENDATIONS

Having now considered the requirements of a good band design and having also obtained experimental evidence on the behavior of the band in a gun, we are in a position to formulate principles that should be followed in design. In the following paragraphs there will be presented fairly definite recommendations in regard to, first, rifling and, later, band design, together with the reasons for each.

DEPTH AND FREQUENCY OF GROOVES AND LANDS

The experiments described immediately above show clearly that the critical factor in the strength of a band as a rotating device is the bearing surface, rather than the cross sectional area of the ridges which resist shear. To increase the bearing surface it is desirable to make the number of grooves in the rifling as large as other conditions will warrant. The frequency of the grooves is usually expressed as the number per inch of caliber. This number is six in some of the older designs, and eight in many of the more recent ones. It is thought that ten grooves per inch of caliber are desirable on the basis of present knowledge. The width of the lands and grooves must be great enough to insure their withstanding the stresses and wear to which they are subjected, and should be no greater.

The bearing surface is also increased by deepening the rifling grooves, but this deepening is limited by the excessive forcing of the band as well as by the weight of the cartridge case in the case of the smaller guns and a great increase over present practice does not seem feasible. It is thought that a depth of .03 or .04 inches in the 75 MM, or gun of equivalent caliber, is desirable and that the depth should increase somewhat less than proportionately with the caliber. The practice of using a conical rifling in which the depth of the groove decreases with the distance from the breech is considered advantageous with copper bands, as this increases the life of the gun while it promotes clear engraving of the band if suitable cannelures are provided in the latter. However, all rifling should now be designed with a view to the future use of rifled projectiles, which require uniform deep rifling without taper, and on this account it is considered that conical rifling should be avoided, and deeper rifling made use of instead.

A consideration of the requirement in rifling design to lessen fringing of the band also makes it desirable to use a large number of narrow lands. The narrower the lands are in proportion to the grooves the less the amount of copper which will be displaced in the process of engraving and the easier it will be to provide a place for the copper to go, without incurring the risk of its flaring out on exit from the gun. It has been found in practice that it is much more difficult to obviate fringing in the case of a gun with broad lands than in the case of one with narrow lands.

PROFILE OF RIFLING GROOVES

The choice of the profile of rifling should be governed by a desire to prolong the life of the gun as much as possible and to secure neat engraving of the band. For these purposes the minimum possible amount of copper should be extruded from the band during engraving and the driving sides of the lands should have a steep slope to prevent their over-riding the band. When the gun erodes, any sharp edges of the rifling will be worn away and they will become rounded. Hence it is desirable from the point of view of prevention of over-riding to make the initial profile of the driving edges rather steeper than would be desirable if they preserved their shape. The use of rifled projectiles seems most feasible with rifling having a radial edge on the driving part of the lands. Taking both factors into account it is considered that a profile of rifling groove with a radial driving side and a smooth slope for the other side is most desirable. The fillets at the corners should be as small as possible consistent with avoiding heat cracks, etc.

UNIFORM VERSUS VARIABLE TWIST OF RIFLING

If a rifling of uniform twist is employed, the stress on the band is proportional at any instant to the powder pressure. It appeared that the maximum stress on the band could, therefore, be reduced by using a rifling of variable pitch to allow the projectile to accelerate relatively slowly in the early portion of its travel when the powder pressure is high. The advantage of such a rifling is apparently much heightened by the simultaneous shifting down the bore of the point where the maximum stress occurs, so that the greatest stress will be withstood by rifling less badly eroded than that near the origin of rifling. It is principally for these reasons that a variable twist of rifling has been strongly advocated and universally used in American artillery.

On the other hand, it is now becoming the universal foreign practice to make use of a uniform twist of rifling exclusively. The reasons which support this practice are briefly as follows:

In the first place, whenever a band of appreciable width is used, the continual change in the angle of rifling during the projectile's travel necessitates a corresponding change in the direction of the engraving of the band. This effect is worse, the wider the band is and is still further accentuated if multiple bands such as are demanded by modern practice are employed. Consequently a band which is otherwise well designed is subjected to a severe mauling when fired in a gun with variable twist rifling and this makes it well nigh impossible to secure that neat engraving which is one of the most desirable objects in band design. Also the facts that the band is subjected to extra strains by the change in the angle of its engraving and that in any case a band will slip slightly under excessive pressure make the total stresses in the band fired through variable twist rifling exceed, in all probability, those in a band fired through uniform twist rifling. A reference to Figure 19 which shows side by side bands fired through guns of uniform and variable twists shows that the physical appearance of fired bands strongly substantiates these views.

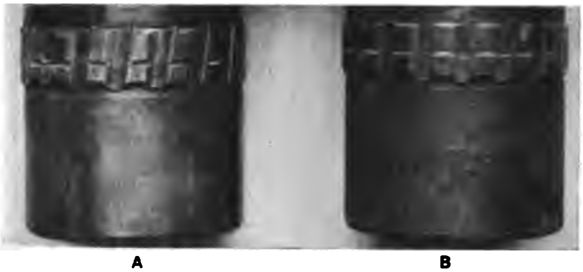

FIG. 19. PHOTOGRAPH OF TWO PROOF SLUGS FIRED FROM GUNS WITH DIFFERENT RIFLINGS
A. FIRED FROM GUN WITH VARIABLE TWIST OF RIFLING. FINAL PITCH 1 - 20
B. FIRED FROM GUN WITH UNIFORM TWIST OF RIFLING. FINAL PITCH 1 - 25

In the second place, the use of variable twist rifling prevents advances in projectile design which could otherwise be made with great advantage. In order to secure satisfactory strength in the rotating device it has been found necessary to employ multiple bands and, in certain cases, projectiles with rifling cut into their steel bodies. In these cases there is so long a bearing surface between the rotating device and the rifling as to prohibit their employment with rifling of variable twist.

Again, the expected increase in life of the gun consequent upon the shifting of the point of maximum stress on the band away from the point of maximum erosion of the rifling has not taken place, so far as such experimental evidence as is at hand indicates.

For all these reasons, and particularly on account of the difficulty in securing good engraving with variable twist rifling, it is very strongly the opinion of the writers that uniform rifling should be adopted in all cases. Our existing artillery may be changed from variable to uniform twist without excessive expense during the natural course of events, by always relining worn guns with liners having uniform twists. If a definite policy were adopted it would be possible to abolish the use of variable rifling within a fairly short period.

In all this discussion of rifling no mention has been made of the possibilities in the way of reducing windage which different systems present, since it is considered that windage has no important bad effects and that its prevention is a matter of very little importance.

SINGLE VERSUS MULTIPLE BANDS

In the case of large projectiles fired at high velocity it is necessary to get a large bearing surface for the band, and if a single band is used it is necessarily very broad. But it is extremely difficult to design a broad band which shall not be subject to fringing and shall satisfy other requirements. To avoid fringing, cannelures, or circumferential grooves, are placed at intervals in such a band. These grooves weaken the band longitudinally so that it is liable to bulge or break under the stress of engraving and under centrifugal forces. To avoid this weakening the band may be made deeper, but in this case the walls of the shell are weakened. The extra length of bearing surface pertaining to a multiple banded shell is also desirable in distributing stresses on the rifling and lessening ballotting in the bore. For all these reasons, it is considered desirable never to exceed a width of about 1 inch in a single band. Wherever greater strength is required than one such band would give, multiple bands should be used. Triple bands have been tried, though with less success than double bands. In cases where more than two bands are required it seems most desirable to resort to rifling the shell itself. The only important objection to the use of multiple bands is that most of our guns have rifling of variable twist. They are, however, only slightly less feasible for use with this rifling than ordinary broad bands are. In any case, the use of uniform rifling is expected to supersede that of variable rifling for other reasons, thus eliminating this objection.

THE LIP ON THE ROTATING BAND

A lip or bead on the rear of the rotating band, as shown in Figure 1, has been universally employed with U. S. major caliber projectiles. The experiments described at length in the first part of this article showed that the lip was a cause of very serious difficulties, but they did not necessarily indicate that the lip could not be preserved in some other form which would retain its advantages and avoid its disadvantages. Nevertheless, it is the opinion of the authors of this article that the use of the lip should be given up entirely and its advantages secured by other means. The arguments for and against the much discussed lip will be carefully gone into in the following paragraphs.

As has been pointed out above, the lip has a very bad effect on the engraving of the band, wherever it is placed. If it is to be preserved some means that will effectually prevent fringing must be provided for disposing of the excess copper. The methods which have been suggested are: (1) in case the lip is at the rear of the band, to make the diameter of the projectile sufficiently small behind the band to ensure that the fringe of copper forced back is thick enough to withstand the blast of the powder gases and the centrifugal force tending to throw it out. (2) to provide a groove in the steel immediately behind the band for the same purpose. (3) in case the lip is situated forward on the band to provide a groove in the copper behind the lip to receive the excess copper. All of these expedients are difficult to apply and depend upon getting the dimensions of the various grooves employed exactly right. Moreover, they are apt to be ineffective in the case of variations in the quality of the copper or in the tolerances in the dimensions of the band. In the case of the 240 MM howitzer, a groove behind the lip gave good results on a number of rounds but a chance round showed very bad fringing.

The chief advantage of the lip is that it provides uniformity of seating after the gun has become worn. In some cases the seating of a projectile with a flat band in a large gun may change by as much as two feet during the life of the gun, and unless a definite stop such as the lip is provided the seating may vary from round to round by several inches. This has been considered a conclusive argument for retaining the lip on projectiles for certain guns despite the other disadvantages. However, this uniform seating may be provided for in other ways, as will be suggested below. The fact that the lip improves the sealing of the bore against windage is not considered an important argument in its favor, as in accordance with statements made above, the effect of windage is considered negligible.

Another serious disadvantage of the lip is that it markedly increases the forcing and consequently increases the wear on the gun due to the friction between the steel and the copper. The fact that the wear is increased by the presence of the lip has been shown by experiments, although they were not very conclusive. By placing serrations on the forward surface of the lip it has been called upon to hold the projectile in place when the gun is elevated, but this purpose also can be served by other devices.

In view of the two serious disadvantages of the lip and the fact that the single important advantage of it can be gained by other means explained below, it is the opinion of the writers that it should be done away with entirely. It has been suggested that bands with lip be used in old guns and bands without lip in new guns but this is considered too complicated a method to be practicable, especially in view of the better solutions of the difficulty which are possible.

Substitutes For The Lip

In order to secure uniform seating, and incidentally to insure that projectiles shall not fall back into the powder chamber when high elevations of fire are employed, there are three feasible methods that have been suggested.

(a) A collar made of heavy paper, rope, or rubber may be employed with old guns which slips over the front end of the projectile and is pushed back until it is held in place by the forward edge of the band. Such a collar could readily be made use of whenever desired and it could be designed in such a way as to insure that the projectile would seat with fair uniformity when it is rammed home. It also could be used to hold the projectile in place when the gun is elevated. In fact rubber tape has been successfully employed for the latter purpose. This collar would be destroyed during firing and would not impede the flight of the projectile after leaving the gun. The questions of fouling of the bore and of flarebacks would have to be provided for by the choice of suitable material for the collar.

(b) A second method is to use a copper ring which would slip over the band and serve the same purpose as the lip, although not being attached to the band proper it would fly off as the projectile leaves the gun. This method has been employed but has objections in that the wear of the gun is increased and that it requires some care to insure that the ring shall serve its purpose and yet not interfere with the flight of the projectile

(c) Another device which will insure a perfect uniformity of seating is to have a couple of small holes in the projectile in which are inserted little plugs of copper resting on springs. Corresponding holes are provided in the chamber of the gun so that when a projectile is rammed into place the plugs engage in these holes and uniform seating is secured.

On firing, the plugs are sheared and fly out of the gun. By providing grooves in the powder chamber in which the plugs may engage on entering the gun, a fairly rapid speed of loading may be secured, although it is somewhat less than the speed usual at present

As a matter of fact the variation of seating from round to round is usually small, and the total change in seating during the life of the gun is not great except in unusual instances. Also most projectiles will stay in place without artificial aid when the gun is elevated if they are provided merely with flat bands. Consequently the provision of a lip or its equivalent is not very important in calibers up to eight inch. The whole question of providing other devices than a lip is one which has not received much consideration as yet and one which ought to be pushed actively. The co-operation of practical artillery officers may well be useful in finding a solution of this question.

DEGREE OF FORCING TO BE EMPLOYED

By forcing is meant the crushing of the copper because of its dimensions being larger than those of the bore of the gun. It has been thought that forcing was desirable because it assures a tighter fit between the projectile and the gun, thus lessening the amount of windage. However, as several times stated in the foregoing portions of this article, it is now considered that windage is unimportant, so that this can not be considered an important advantage of forcing. Another effect of forcing is to slightly delay the start of the projectile on account of the greater force required to engrave the band, and this effect may result in a higher muzzle velocity by reason of the extra time of burning allowed the powder, in spite of the greater frictional losses. This effect of forcing is not considered especially important, one way or the other.

The important advantage of forcing is that it somewhat increases the bearing surface, especially in a worn gun and consequently increases the degree of erosion allowable before a gun is worn out. However this gain is slight and on the other hand the extra friction in the gun increases the rate of wear of the latter and so shortens the time required to reach a given state of erosion. Consequently the degree of forcing should be so chosen as to strike a suitable compromise between these two considerations. If the rotating band diameter is insufficient to fill the grooves of the gun the ridges on the band are likely to give slightly under the bearing pressure so that fins of copper are forced up into the vacant spaces with objectionable results. On the other hand if its diameter is large an excessive amount of copper is pushed back and fringing is very hard to avoid. It is difficult to say exactly what the diameter of the grooves of the rifling should be taken to be, as this depends upon the degree of erosion of the gun and varies appreciably when the gun is heated or expanded in firing.

It is thought that making the external diameter of the band from .01 to .02 inches larger than the diameter across the grooves of a new gun is the most suitable amount of forcing to adopt for the 75 MM caliber. The excess diameter might well be larger in the case of major caliber guns, however. When new bands are being designed, samples of several different diameters should be prepared and fired for recovery.

Shape of The Band

Assuming that plain bands, single or multiple, are to be employed and that no lip is to be provided, there still remain several questions to be settled in regard to the profile of the band. It has been recommended that the width of any band should not be more than about one inch, and that its maximum diameter should be about .02 inches larger than the maximum diameter of the rifling.

The front of the band should have a fairly steep slope, the angle between the line marking the front slope and the axis of the shell being about 60°. If a very gradual slope is employed such as appears in the case of the 4.7-inch band shown on Figure 6, the entire width of the band is not utilized. Also fringing at the forward end is likely to result from small fins of copper being squeezed out by the bearing pressure between the lands of the gun and the band. This fringing may be quite objectionable in the case of a gun with an increasing twist of rifling. If a perpendicular front on the band is employed, a slightly increased resistance is presented to the air in flight and also in the initial engraving of the band by the rifling the pressure is exerted directly to the rear with a consequent large tendency to buckle the band. If a slope is employed at the front, this initial pressure of engraving has a component downwards holding the band in its seat in a desirable manner.

The rear of the band should also have a slope. This is to provide against fringing due to the rearward motion of excess copper producing an overhanging fringe at the rear. If a rectangular shape of the rear is employed fringing is sure to result, while if too gradual a slope is employed the width of the band is not well utilized. Also in the case of fixed ammunition, the cartridge case will over ride the band during assembly of a complete round unless the rear of the band has a sufficiently steep slope or the slope begins at a great enough diameter to leave a portion of the rear of the band vertical to form a stop. It was on these principles that the particular type of rear profile adopted in the case of the 4.7-inch band shown on Figure 6 was chosen. As in the case of that band, it is nearly always found desirable to provide a small groove in the steel immediately in the rear of the band as an added precaution against fringing and as a useful crimping groove for cartridge cases, when they are employed.

In order to reduce the amount of excess copper to be taken care of in the design of the rear profile of the band, it is advisable to provide one or two cannelures in the band like those illustrated on the 155 MM howitzer shell shown in Figure 11. These grooves must not be deeper than necessary to take the excess copper. Usually they are made of the same diameter as the lands of the gun.

CONCLUSIONS

Summarizing the recommendations made, the following four conclusions may be drawn:-

1st: The rifling of the gun should be made with uniform twist. Approximately ten grooves per inch of caliber should be employed. The width of the grooves should be somewhat greater than that of the lands. The depth of groove should be .03 or .04 inches in the case of the three inch gun or gun of equivalent caliber and should increase approximately proportionally with the caliber. The use of conical rifling is not recommended. The profile of rifling grooves should have a radial bearing edge and a gradual slope on the other side.

2nd: No rotating band should have a width greater than about one inch, two or more bands being employed when greater strength is required than one band would give. When three or more bands of this width would be required rifling cut in the steel shell should be employed.

3rd: No lip should ever be employed, equivalent devices such as paper, fiber, or rubber collars being made use of to insure uniform seating in old guns. The amount of forcing should be that given by having the maximum diameter of the band about .02 inches larger than the diameter called for by the grooves of the rifling, for medium caliber guns.

4th: The band should be designed in such a way as to provide the best possible engraving. To this end a fairly steep slope at both front and rear should be employed and proper cannelures, or circumferential grooves, should be provided. The general appearance of the band in profile should be similar to that shown in Figure 20.

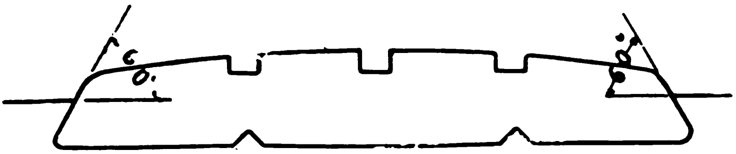

FIG. 20. RECOMMENDED BAND

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The Service of Anti-Aircraft Artillery

By Lieut. Col. O. L. Spiller, C. A.

In the May number of the JOURNAL of the U. S. ARTILLERY there appeared an editorial on the subject of the Anti-Aircraft Service in which the discussion took the form of an argument to justify the existence of such a service. Since that date, however, the Atlantic has been crossed by three different types of Aircraft. In two of these flights the machines took off from one hemisphere and were continuously in the air until they landed in the other. With such feats already accomplished we need not tax our imagination to picture the powerful air offensives that are to be staged in the very beginning of a future war. It is safe to say that the refinements of aerial warfare will soon surpass anything that the average American can now imagine.

Suppose that in 1914 someone had delivered to an American audience a lecture describing the rôle that heavy artillery was to play in the European war, and had described a few of the huge calibers that were soon to be rendered mobile by the use of tractors and railway cars. The average listener would have sized him up as a dreamer attempting to paint an absurd picture. And what was the opinion of the average of us in August 1914 when we read dispatches in the papers to the effects that "heavy 42 cm Howitzers are traveling behind tractors over the roads leading westward toward Liege and Namur"? Did not we think that there was some joker in that similar to the one in the famous communiqué which was sent to Macbeth about Birnam Wood moving to Dunsinane? Yet in four years from that date such types of mobile ordnance were as common in our army as the three inch field piece had been in 1914.

Other view points than our own may be found in a prominent British Military Journal where we find in one of their editorials this statement: "It is agreed on all sides that the opening scenes of a future war will be laid in the air. Anti-Aircraft gunnery seems, therefore, to step into the premier place. Is this conclusion correct? And if it is correct is Anti-Aircraft gunnery being given the place it claims?" This same paper quotes the following statement of a distinguished French Artillery Officer, "Anti-Aircraft Artillery is only beginning. Aerial Warfare is extending more and more, and sooner or later the empire of the earth will belong to those who are capable of ensuring that of the air."

Now let us proceed to a discussion of the Anti-Aircraft Service, granting that its existence is justified. The part which interests us most is naturally the Anti-Aircraft Artillery. This type of Artillery during the past war was manned entirely by the Coast Artillery. It was a new science and it was our job to develop it as far as the American Army was concerned. In this connection it is interesting to note that practically the only literature that has appeared in this country on the subject of Anti-Aircraft Artillery was written by Coast Artillery Officers. As far back as the early months of 1917 articles on this subject appeared in the JOURNAL of the U. S. ARTILLERY. One of these articles dealing with the weapons and fire control methods in use at that time is very interesting even at this later date. It describes in exhaustive detail the different types of matériel and deals with principles of fire control which have lately been developed along the lines that were then prophesied. Unfortunately the author who had made such a thorough and conscientious study of this subject rendered his last service to the country in the Argonne Forest last November.

Thus it may be seen that officers of this service were giving thought to this undeveloped branch of Artillery long before the War Department had made any decision as to who should furnish the personnel for it. It now forms one of the important types of artillery with which the Coast Artillery officer must become familiar. Some of us may be trying to choose the particular type in which we wish to specialize. If we know more about some of the different types we can more easily make our choice, provided policy will allow us to do so.

Little is known of Anti-Aircraft and the object of this article is to give a general idea of what Anti-Aircraft is like in its present state, and to show wherein lie the opportunities for future development.

The mission of Anti-Aircraft is to protect our military forces and establishments from both hostile observation and attack from the air, and to assist the Air Service in their missions of a similar nature.

The tactical employment comes under two general heads:

1st, front line defense against all types of aircraft.

2nd, defense of back areas such as headquarters, depots, railroad yards, cities and towns against observation and bombing.

During the war this came under three divisions—the lines of communication, dumps, Headquarters, etc., constituting a class in between the front line and the fixed rear areas. But the availability of matériel will allow some simplification of the problem since these more or less temporary localities can be defended by the same type of mobile matériel as is used in the front line work.

FRONT LINE DEFENSE

Matériel used for front line work is very mobile, capable of taking up new positions readily. Its normal position is from two to five kilometers behind the front line as shown in the following sketch. It is organized into sectors (battalions) as shown later, and is a part of the Army Artillery. In our present organization eight sectors are assigned to an army.

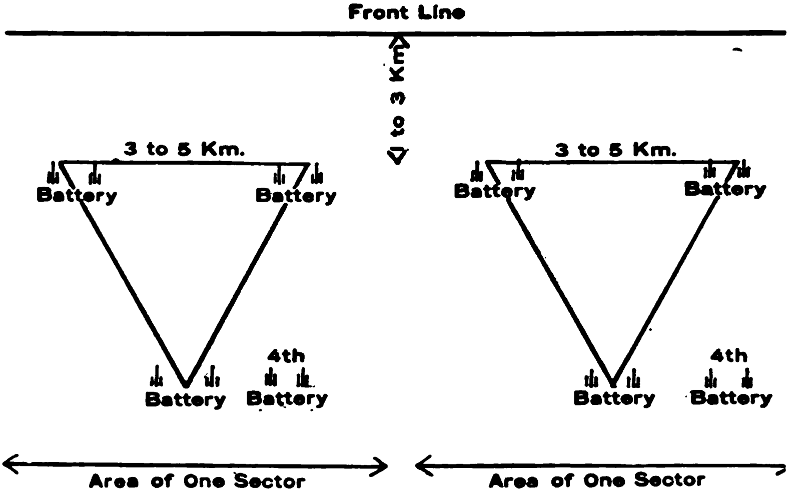

FIG. 1.

The arrangement shown above is what was adopted in the American Army and it is believed that it accomplishes what was aimed at in all the allied armies tho the dispositions may be slightly different.

One of the earlier methods, from which this was developed, provided two lines of batteries parallel to the front. In the first line at a distance of one to three kilometers from the front, the guns were grouped in ones, twos, and occasionally threes, about three kilometers between groups so that their fields of fire would overlap at an altitude of 3000 meters. A second line of batteries was placed in echelon two to three kilometers in the rear of the first so as to support the fire of those in the front lines.

A later refinement of this method consists in placing three batteries of a battalion (or group) at the vertices of an equilateral triangle as shown above. The first two batteries being on a line at a distance of one to three kilometers from the front. This is practically the same as our method except that we have a fourth battery in the sector which may be used either to strengthen the second line or to reinforce the first. Or, if local conditions demand it, this fourth battery may be temporarily attached to a nearby sector. One great advantage of this method is that it favors the grouping of Anti-Aircraft Searchlights in their positions near the batteries so as to allow the maximum cooperation. The most effective method of combating night bombers at the front is to send up our fighting planes which are guided by the searchlights and supported by the artillery. Proper execution of these details requires the closest liaison between the Air Service and the Anti-Aircraft Service.

Experience has shown that this number of guns, 64 per army, is entirely inadequate in a locality that is at all active. It may be very desirable to have a third line of guns, since the guns of the first line have difficulty in firing at night. Their positions are easily disclosed, and they are then subject to hostile artillery fire. With a third line of guns the first resistance to night bombers could be put up by the second and third line batteries. This increase in the number of guns could be made without materially affecting our present sector organization since that organization is sufficiently flexible to allow the addition of one more gun per battery or the assignment of one or two more batteries to a sector. But the most satisfactory procedure would probably be the assignment of a greater number of sectors to an army.

The latter would be in conformity with the recommendation of the Westervelt board which would place Anti-Aircraft Artillery in the General Artillery Reserve; the assignment of it to field armies is made by the Chief of Artillery in accordance with the needs of those respective armies. The Anti-Aircraft Units assigned to an army are commanded by the Army Anti-Aircraft Commander who is on the staff of the Chief of Artillery of the Army.

The assignment of sectors to their areas along the front is made by the Army Anti-Aircraft Commander, and the batteries are in turn assigned to their positions by the Sector Commanders. In choosing a battery position the same considerations should be given to proximity to roads or to terrain that can be crossed, that govern with other types of motorized artillery. One requirement that is peculiar to Anti-Aircraft Artillery is that the angle of *site* should not be less than 15°. This means that the line of *site* of the gun should not come below that angular limit and that the line of *sight* (vision) of the gun pointer should not be obscured anywhere above 15°.

The guns will habitually be placed and fired in groups of two or more. Due to the ballistics of Anti-Aircraft fire, the great speed of the target and its ability to move freely in three dimensions it is considered much more efficacious to fire a few salvos from two guns singly controlled than to fire a much greater number from two guns firing independently.

For this reason some authorities urge the mounting of guns in groups of four or even more—the number being extended up to the point where unity of control is lost. In the defense of back areas this larger grouping could be more easily and economically carried out than at the front.

DEFENSE OF BACK AREAS

In the defense of back areas some mobile artillery is used so that positions can be frequently changed but most of the matériel is of a fixed or semi-fixed type, more or less permanently emplaced with elaborate communication and fire control systems. The number and disposition of batteries required to defend a back area depend upon the location and importance of vulnerable targets. The guns should be arranged so as to provide a concentration of fire along the most probable lines of approach of enemy Aircraft. Due consideration should be given to placing the guns properly with reference to other important elements of the defense, such as listening apparatus, searchlights, machine guns, etc. One of the important features of these defense areas is a system for giving adequate warning throughout the defense areas, and to the nearby civilian population, of the approach of enemy aircraft.

These systems form a part of an immense network of observation and signal stations extending all the way from these areas to the front. The workings of this system should be so perfected that no hostile aircraft could approach any area before adequate warning has been given. It is also very important that proper measures be taken to prevent turning in false alarms. According to an estimate made at the British War office, one false alert sounded in London in the early part of the evening might cause an industrial loss of more than a million dollars. Even if the "all clear" is sounded within a short time not enough of the workmen go back to their places to allow the factories and shops to operate normally. This would be a serious handicap, since the output of most of these concerns is war matériel.

One or more sectors are generally assigned to the defense of an area. All the elements of defense in an area are under the immediate command of a local defense commander.

MATERIEL

We were not very fortunate in the matériel which reached France from this country. No suitable mount for front line work was furnished. Eighteen truck mounts with the 75 mm gun reached France, but the necessary alterations to remedy all the defects could not be made before the fighting was over. The principal defects were that the gun could not be depressed below 31°; the mount was so unstable during firing that the gun crew could not "stay with it"; the instruments could not be kept set, and the elevating and traversing mechanism jammed so that a target could not be followed. The mount was so encumbered by several heavy iron beams, evidently intended to stabilize it in the firing position, that it was by no means mobile. All of our troops at the front used French matériel, either the auto-cannon, trailer or semi-fixed mount, all with 75 mm guns.

The American trailer mount offers posibilities as a mobile type. It carries an excellent gun—3 inch, 2600 f. s.—the highest powered mobile gun yet used for anti-aircraft work. It has a semi-automatic breechblock. The carriage is drawn by an F. W. D. Tractor. These were not furnished in time for use in France but it is understood that they are now on hand in great quantity. See Figures 2 and 3.

The type known as the improvised semi-fixed mount with the 75 mm gun was, after further improvisations over there,

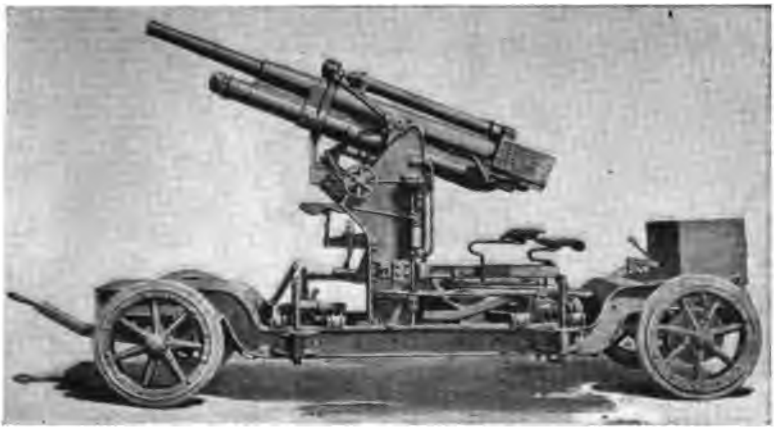

FIG. 2. 2150

AMERICAN 3-INCH ANTI-AIRCRAFT TRAILER MOUNT. TRAVELING POSITION

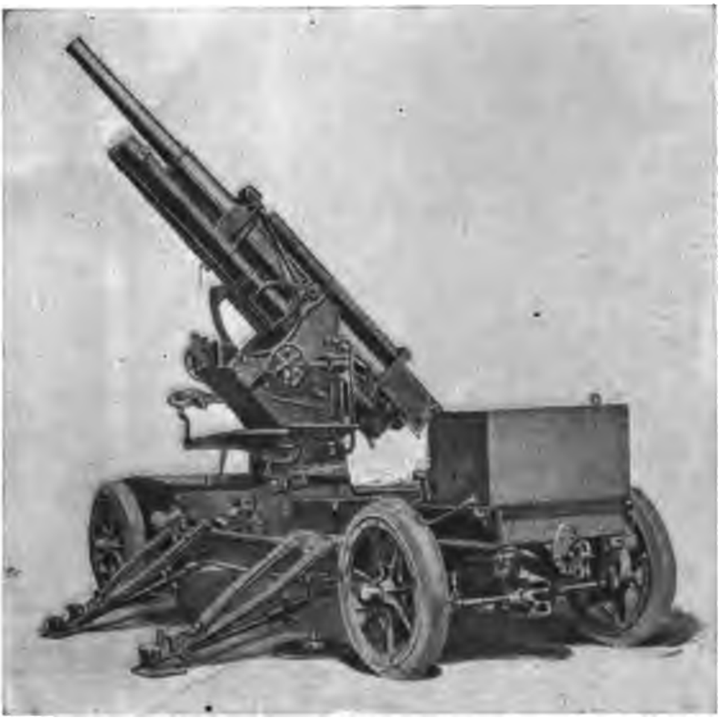

FIG. 3. 2451

AMERICAN 3-INCH ANTI-AIRCRAFT, TRAILER MOUNT. FIRING POSITION

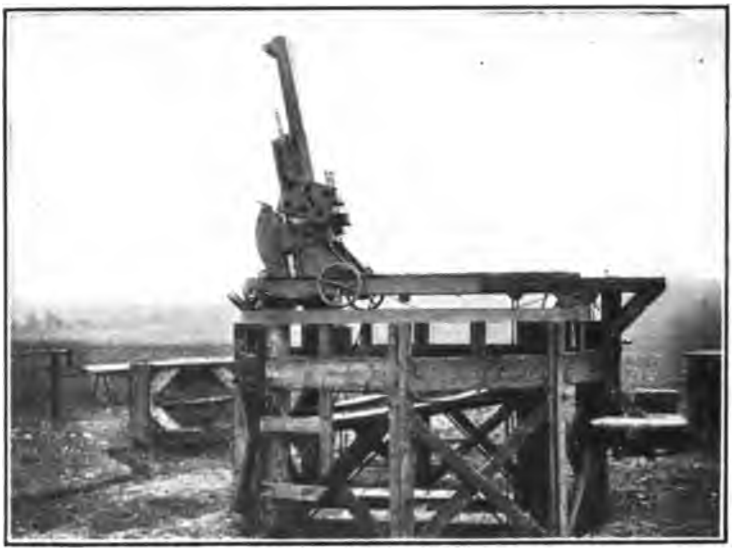

FIG. 4. 2153

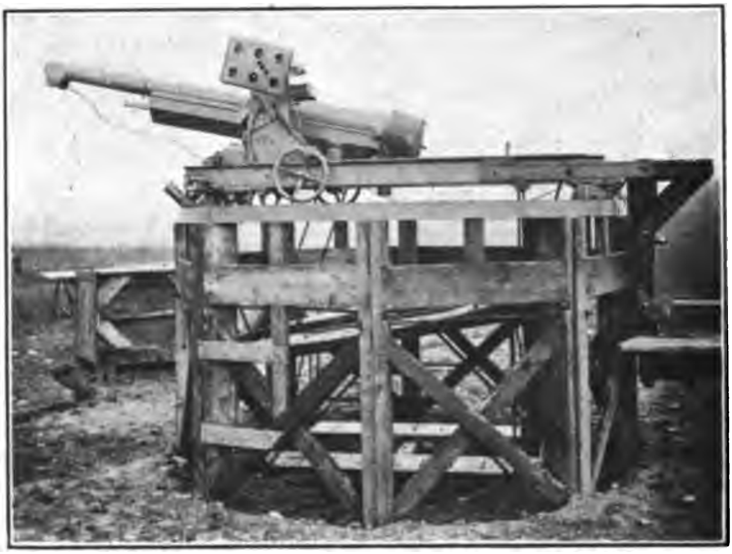

FIG. 5. 3453

used for back area defense work. About thirty of these were installed and were being manned at the time of the Armistice. However, this mount, as finally turned over to us by the Ordnance Department, was difficult to emplace, requiring at least two days labor and considerable matériel. But a very ingenious modification of it, as shown in Figures 4, 5, and 6 was designed by an Anti-Aircraft Artillery officer. (Major. R. R. Robertson, C. A., (Reserve). Matériel required for the construction was picked up in a railroad yard and the work was done by battery mechanics. The framing is made in movable panels, and can be easily knocked down and transported in trucks. As modified the mount can be set up and taken down in four hours. The first four guns mounted in this fashion had their initial test in a three hour fight with a very determined group of nine Fokkers who kept up their efforts to bomb a very important advance depot until the four guns had fired nearly 300 rounds. The bombers finally gave up the fight after having done no more damage than to drop some bombs in the woods about two miles from their objective. The new mount stood this test perfectly and was generally satisfactory.

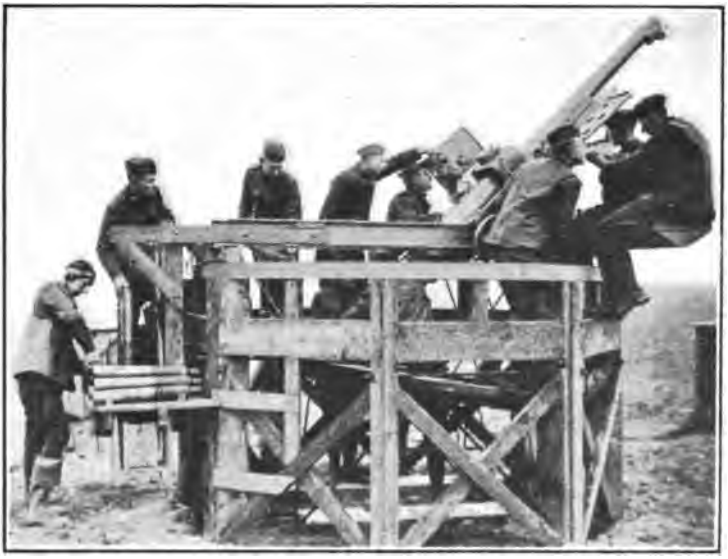

FIG. 6. 2464

Anti-aircraft guns and mounts should fulfill the following requirements:

GUNS

1. *Long Range.*—When the angle of site is 45 degrees and the altitude of the target is 5000 yards the range is over 7000 yards. The average range in the future will probably exceed this, since aircraft can now accomplish many of its missions while flying above 5000 yards altitude.

2. *Rapid Fire.*—A minimum of 10 shots per minute for 10 minutes.

3. *High Velocity.*—The present American 2600 f/s gun permits the target to travel about one mile during the time of flight for the average range.

4. *Long Life.*—Approximately 1500 rounds per gun, per month were fired during active periods in France, and this may be exceeded in future wars. Therefore considerations of replacement are important.

5. *Fuze Setting.*—Fuze setters should be automatically operated by the laying of the gun, and means should be provided for applying independent corrections for such items as time lost in loading, variations in lots of fuzes, etc.

CARRIAGES

1. *Field of Fire.*—All around fire, and from 0 degrees to 80 degrees elevation.

2. *Mobility.*—Should be capable of being used on ordinary roads, and should permit firing from a level platform within five minutes after halting.

3. *Laying*—Continuous laying should be practicable. The promising arguments for this seem to be "altitude" and "angle of site" (or quadrant elevation). Elevating and traversing mechanisms should be very carefully designed.

4. *Deflection Scales.*—These should permit of lateral and and vertical corrections up to 450 mils. Indices should be movable on secondary scales up to 50 mils for independent corrections, such as wind.

5. *Sight* mechanism should be easily tested and adjusted.

6. *Scales* for azimuth and quadrant elevation should be provided.

To sum up, a suitable mount for Anti-aircraft fire should elevate between the limits of 0 degrees to 80 degrees and should have all around fire. The elevating and traversing mechanisms should work lightly and rapidly, and the breechblock and ammunition should permit of very rapid loading and firing–since some targets move at the rate of two miles per minute.

In attempting to meet these requirements the following points must be considered:

*1. Weight of weapon.

2. Weight and type of projectile.

3. Features contributing to certainty of action and convenience of service.

4. The best organization for development and tactical use.

5. The co-ordination of its matériel with that of other branches.

In the design of any gun it is necessary to strike a balance between the conflicting factors of range, mobility, rate of fire, power and life, and the weapon which possesses these features in the highest degree is the most efficient one.

The Westervelt board recommends two types of guns for Anti-aircraft work, the light gun being the 3-inch, and the heavy gun to be of 4.7 to 5-inch calibers. Both are to satisfy the following requirements: "—with initial velocity of at at least 2600 f.s.; semi-automatic breechblock; mounted on a carriage permitting 80 degrees elevation and 360 degrees traverse; projectiles weighing not less than 15 pounds for 3-inch gun, 45 pounds for heavy gun; one type H.E. shell with maximum ballistic qualities and as large bursting charge as practicable; fixed ammunition; smokeless flash powder; mechanical fuze—"

Transportation for each type is prescribed as follows: Light Gun: "Caterpillar mount or caterpillar trailer mount drawn by caterpillar tractor, each unit to permit a sustained speed of 12 miles per hour."

Heavy Gun: "Self-propelled caterpillar mount permitting sustained speed of eight miles per hour with maximum weight not to exceed ten tons, trailers to be provided for long and rapid hauls."†

Two problems that are to be solved by improvements in the matériel are:

1. Reduction in the time of flight.

2. Producing a larger volume of effective explosion.

When firing at aircraft at a range of 5000 to 7000 yards the average time of flight is more than 30 seconds. This

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* From an article by Col. Forrest E. Williford on Trench Artillery.

† Proceedings of Westervelt board Par 64-69 published in Journal of the U. S. Artillery for July, 1919.

means that some types of targets will travel 1760 yards during the time of flight and if flying at right angles to the plane of fire the lateral deflection due to motion of target alone is 440 mils (hence the necessity for deflection scales as stated above.) Besides this the Anti-aircraft Artilleryman has to worry about his vertical deflection, the enormous change in range and the effect on the elements on vertical and lateral deflection and upon range. The most obvious means for erducing the time of flight is to increase the M. V. This, of course, decreases the life of the gun and a limit will have to be determined. But a proper economical solution of the problem may not show that, all things being considered, there is any waste in renewing a gun now and then to accomplish the desired results. It is almost universally the conviction of Anti-Aircraft Officers of all the allied armies that the guns should be larger and of higher velocity than the 3-inch, 1700 f.s. gun. Another effort which has been made to increase the velocity is to omit the rifling in the gun. Information has been received from a reliable source that experiments with a smooth bore rifle were actually being conducted but the results of these experiments are not yet known.

The obvious solution of the second problem is to increase the caliber of the gun. Here we encounter the difficulty of keeping up the rate of fire, for our target is still rushing madly on at 120 miles per hour (not mentioning influence upon time of flight). Guns of about 4-inch caliber have been designed abroad and are now being manufactured for experimental purposes. It is probable that the ammunition experts will provide satisfactory solutions of these problems.

One suggested method to reduce the time of flight is to give the projectile a stream line form and possibly to provide a tail and horizontal fins, since anti-aircraft fire utilizes almost excusively the ascending branch of the trajectory. Possibly the time of flight may be reduced by improvement of the powder train of the fuze. As we increase the angle of site, the time of flight for the same range becomes greater due to the larger component of the force of gravity that acts along the trajectory. The decrease in density of the air as the projectile rises from the earth diminishes the supply of available oxygen, thereby causing the powder train to burn more slowly. These two effects counter-act each other to a certain extent, but the net result is that as the angle of site is increased the range to the burst is decreased. Further discussion along this line would come under the subject of Fire Control methods but this subject has been fully treated in an article by Major Glenn P. Anderson which has already appeared in the September issue of the JOURNAL U.S. ARTILLERY.

One type of shell has been designed with its inner walls weakened so that upon explosion it will break into longer and larger fragments. It is believed that this will result in a decidedly more destructive effect of the explosion. The most effective ammunition used in the war was high explosive. A great deal of shrapnel was fired up to 1917 on account of its availability but during the last year H. E. was used almost exclusively except for night barrage work. The H. E. accounted for most of the enemy planes that were brought down. The time fuze was used with both H. E. and shrapnel.

A hasty reading of the above should give the average officer an idea of how little the requirements of Anti-Aircraft Artillery have been satisfied. In other words, it is a science still in the experimental stages and it affords wonderful opportunities for those who would care to be connected with the development of a very interesting and necessary branch of artillery.

"Of course the design and construction of this matériel is the function of the Ordnance Department, but to enable them to supply us with a suitable equipment the requirements of the Artilleryman must be clearly set forth." *

ORGANIZATION

In the allied armies there was the greatest divergence of ideas respecting the organization of Anti-Aircraft Units. Generally speaking, the following features were practically the same throughout all the armies.

1. The higher organizations, i.e., of units attached to field armies and to the rear defense areas.
2. The classification and employment of Anti-Aircraft Units as army troops.
3. The motorization of all organizations assigned to matériel used in front line work.

Some had no regimental orginazation and where it did exist it was chiefly administrative, the regimental commander having nothing to do with the tactical disposition and operation

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* From "Railway Artillery for Seacoast Defense," by Lt, Col, Fred M. Green C. A. in June 1919 Journal U. S. Artillery, Page, 353.

of the units. As a rule the batteries were organized in independent battalions. In some cases these battalions were compact tactical units and were held together and employed as such. In others the battalion was quite flexible. The basis of the organization seemed to be, to a certain extent, geographical, with a view to covering a certain section of the army front. The number of batteries assigned to a battalion was determined by local conditions, such as the terrain and aerial activity in its particular sector. This feature of the French organization gave rise to our sector organization.

When our first anti-aircraft artillery units were formed from the Coast Artillery they were organized in two different ways. The batteries which were to man motorized front line matériel were organized in battalions of four batteries each, a Headquarters and Supply company. The batteries that were to man semi-fixed matériel in the defense areas were formed as independent organizations and were grouped together in the defense areas under a local defense commander who had to form the Headquarters and Staff from the personnel of the various batteries

In October 1918 all the units in the A. E. F. were organized in accordance with new tables prepared by G. H. Q. which prescribed the sector organization. This provides a uniform strength for all batteries, regardless of the matériel to be manned. A sector consists normally of a Headquarters and Supply company, and four batteries, though the number may vary from three to six in accordance with the local needs. This allows a great deal of freedom in shifting the units from one part of the front to the other, and for relieving troops, either by entire sectors or by batteries, from service at the front and interchanging them with corresponding units serving in the back areas. All the units were motorized but those serving in defense areas were to be issued only the transportation necessary to meet local needs; the rest to be pooled at a replacement center.

The battery organization of the future wil probably be a four gun unit. The two gun battery organization is not economical as regards personnel, supply and motor equipment. The only thing that will limit the number of guns will be unit tactical control–this means control on the road, in position, etc., as well as control of fire. The Italian organization consists of four gun and six gun batteries.

As has been stated before the commander of the Anti-

Aircraft defenses of an Army is on the Staff of Chief of Artillery of the Army. He is in command of all the anti-aircraft units—artillery, machine gun and search lights—assigned to the army. In our organization this officer is a colonel, and has on his staff one officer from each of these branches of anti-aircraft defense.

The Headquarters of the Anti-Aircraft Service was a G. H. Q. agency. The Chief of the Anti-Aircraft Service commanded all the various elements of Anti-Aircraft defense as well as the training centers and schools.

As this article has been devoted to Anti-Aircraft Artillery, no discussion has been made of the two other highly important branches—Anti-Aircraft Machine Guns and Anti-Aircraft Searchlights.

OTHER BRANCHES OF ANTI-AIRCRAFT

Seven Anti-Aircraft Machine Gun battalions reached France, three of which rendered very efficient service at the front. They afforded practically the only defense against low flying craft. They were equipped with an ordinary Hotchkiss machine gun fitted for high angle fire by an improvised "avion-extension", the gun being reversed in its trunnions. They were provided with a special sight which gave the proper amount of "lead" on the target. The battalions were motorized, four companies were in a battalion, each manning twelve guns.

The 56th Engineers was an Anti-Aircraft Searchlight regiment, two companies of which began their activities in a very lively sector between Amiens and Montdidier, early in May 1918. Toward the end of October these organizations began to demonstrate the fact that the "Hun bird could be caught in the beam and held there" despite the advice of several critics who assured them it could not be done, and in the first and second American Army areas they proved that they were able to pick up and follow the enemy planes well enough for our fighting planes to go up and engage them. All the companies were motorized; the equipment consisted of a portable dishpan light transported on a Mack Truck, the power plant for the light being run by the truck motor. The company consisted of five sections of fifty men each; each section could man from two to three lights.

CONCLUSION

A great many artillery officers look upon Anti-Aircraft gunnery as so much guess work. The average artilleryman wants to hit and if he doesn't see immediate results he thinks the gunnery is at fault. "His 'commonsense' requires us to bring down an airplane as one brings down a partridge with a gun. "Commonsense is the fruit of ancestrial experience and Anti-Aircraft gunnery has existed only since the war. It is commonsense which is wrong in refusing to see our difficulties, it is commonsense which must be reformed. Anti-Aircraft gunnery may seem like a game, but it is a game in which luck is peculiarly favorable to the good player." We will still have hope if the ammunition experts keep sufficiently apace with the aeronautical sharks so that the airplanes of tomorrow will not travel faster than our projectiles. It must be remembered that for Anti-Aircraft Artillery all of the fire control methods have been devised, and the matériel has been designed and manufactured during the stress of a war which was already demanding the maximum of the thinkers' efforts besides the maximum of the factories' outputs. Before 1914 there had not been sufficient advancement in aeronautics to justify any nation to make preparations against attacks from the air.

If in the future we are found lacking in such preparations can we offer any such excuse? We have been amply forewarned; are we going to be forearmed?

Deviation Computer for Moving Target for use on Whistler Hearn Plotting Board

By *Lt. Col. J. H. Pirie, C. A.*

There was published in the JOURNAL U. S. ARTILLARY for March-April, 1917, an article by First Lieutenant Cecil G. Young, C. A. C., on the subject of "Observation of Fire" but it did not attract as much attention from Coast Artillery officers as it would have, had it been published at any other time. The discussion dealt with the problems involved in adjustment of fire based on observation from shore stations, during the use of fixed armament against moving targets and the devices and methods suggested were designed with a view to the solution of those problems. The United States had just entered the European War and Coast Artillerymen were primarily interested in the use of heavy artillery in land warfare.

It had been found that adjustment of fire as a result of observation is always necessary, so when the First Brigade of Railway Artillery was mobilized for duty in France each battery was equipped with a "T.O.B. Clock." This was a device designed by the Coast Artillery Board for the purpose of reducing the angular deviations observed by terrestrial observers to deviations expressed in yards, over or short, and yards or mils, right or left of the battery target line.

This device was replaced in France by the use of simple charts. At a later date the Pirie Deviation Board (a development of the T.O.B. Clock) was prescribed for general issue and this in turn was superceded in the equipment tables by a modified form of the same device called the Uncles Deviation Board.

These devices were all designed with a view to their use in land warfare and so were not suitable for use in connection with firing on a moving target.

During the Long Range Fire Control Tests held at Fort Hancock, New Jersey, by the Development Division, Training Section, Coast Artillery Training Center, a modified form of the Uncles Deviation Board was made up and used but

it was found to be inaccurate and inconvenient and its operation too slow to allow for its efficient use in the adjustment of fire against a moving target.

To take care of this part of the problem of long range fire control the Development Division then designed the Deviation Computer for Moving Target for use on a Whistler Hearn Plotting Board as described below:

Description

The device consists of a disc (1) See Fig. 1., fifteen inches in diameter carried on a pin at the outer end of an arm (2) to be substituted for the gun arm of the plotting board. On the surface of the disc is a quadrille graduation as shown to a scale of 200 yards to the inch so that an impact may be plotted at any point within 1500 yards of the center of the disc. The disc does not revolve so the graduations are always properly oriented. A method is provided for attaching tracing paper over the disc so that the deviations, "Over" or "Short" and "Right" or "Left" in yards may be read through the paper and a permanent plotted record be obtained of each observed impact.

There is pivoted on the pin supporting the disc, between the disc and the gun arm, a short arm (3) carrying a board upon which is mounted a T-square (4), a tangent scale chart (5), and two target distance markers (6).

The gun arm is graduated on a scale of 1000 yards to the inch, least reading 100 yards, and is held in a sleeve (7) through which it is free to slide. This sleeve is pivoted on the outer end of a short arm (8) and is free to revolve in the vertical and horizontal planes.

The short arm (8) is held in an adjustable clamp (9) so that the sleeve (7) may be set to a position to correspond to the displacement of the directing point of the fort or battery from one of the observation stations, "A-1" or "A-2", of the base line used for fire adjustment. The clamp (9) is arranged so that it may be clamped at any position along the rib on the top of the base line arm of an ordinary Whistler Hearn plotting board after the gun arm and its slide have been removed

With the addition of the apparatus just described and of specially graduated "A-1" and "A-2" arms (10) and (11) and with the gun arm mechanism removed, the Whistler Hearn plotting board is used without further modifications.

It will of course be necessary to use an azimuth circle graduated to correspond to the azimuth of the "A-1", "A-2" base line and to use a coupler of a proper length, on a scale of 1000 yards to the inch, to correspond to the length of the base line.

The arms (10) and (11) are both of the same width and graduated on a scale of 1000 yards to the inch. The zero of the graduations is displaced from the station pivot a distance corresponding to the distance from the center of the disc to the outer edge of the board carrying the T-square and tangent scale chart. This is in order that the range to the intersection of the station arms may be read at the edge of the board when the disc and board are in position as shown by the dotted lines in Fig. 1.

In order to provide a support for the tangent scale chart when the target is near one of the observation stations, the station arms are shown extended to the rear, beyond their station blocks. This arrangement would very often cause mechanical interference so it will probably be found that a better way to provide for the condition in which the target is near one of the observation stations, is by having the station arms terminate at their station blocks as in the case of an ordinary plotting board and then provide a double graduation on each arm. The second graduation would have its zero at the same distance from the station arm pivot as the zero of the first graduation but on the opposite side of the pivot. Then when the target is near one of the observation stations the tangent scale chart board would be placed outside the disc on that station arm and the range to the intersection read at the edge of the tangent scale chart board, on the second scale. In this case an angular deviation seen to the right from that station would be set on the side of the tangent scale chart marked "Left" but the deviations on the scale on the head of the T-square would be set as graduated.

Referring to Fig. 2 it is seen that the T-square (4) has a head at each side of the tangent scale chart board and that the blade of the T-square is pivoted on one of these heads at (12) and is held in position opposite a degree scale on the other head by a screw (13) having a micrometer head. This allows the T-square blade to be set at an angle, to the station arm over which the tangent scale chart is centered, corresponding to the deviation angle observed from that station.

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The gun arm is graduated on a scale of 1000 yards to the inch, least reading 100 yards, and is held in a sleeve (7) through which it is free to slide. This sleeve is pivoted on the outer end of a short arm (8) and is free to revolve in the vertical and horizontal planes.

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Referring to Fig. 2 it is seen that the T–square (4) has a head at each side of the tangent scale chart board and that the blade of the T–square is pivoted on one of these heads at (12) and is held in position opposite a degree scale on the other head by a screw (13) having a micrometer head. This allows the T–square blade to be set at an angle, to the station arm over which the tangent scale chart is centered, corresponding to the deviation angle observed from that station.

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Referring to Fig. 2 it is seen that the T-square (4) has a head at each side of the tangent scale chart board and that the blade of the T-square is pivoted on one of these heads at (12) and is held in position opposite a degree scale on the other head by a screw (13) having a micrometer head. This allows the T-square blade to be set at an angle, to the station arm over which the tangent scale chart is centered, corresponding to the deviation angle observed from that station.

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The tangent scale chart has a range scale at each end for setting the target distance markers. These range scales are on a scale of 4000 yards to the inch and are shown from 2000 yards to 40,000 yards. The tangent scale chart board is mounted at a distance from the center of the disc so that the zero range line is eight inches from the center of the disc.

The diagonal straight line graduations on the tangent scale chart are located as follows. To find the perpendicular distance "a" from the central line of the tangent scale chart at which a given angle line "φ", as for example 2 degrees, intersects a given range line, as for example, 30,000 yards, the following formula is used:

$$a = R - (8 + \frac{R}{20})\operatorname{Tan}\varphi \qquad \text{where}$$

R is the range in inches on a scale of 200 yards to the inch.

a is the distance along the range line on the tangent scale chart to the intersection of that line with the diagonal graduation line for the angle φ. This distance is in inches.

8 is the distance in inches from the center of the disc to the zero range line on the tangent scale chart. If the device is manufactured so that this distance is not 8 inches the proper number is substituted here.

The distance "a" for various angles of deviation can be found for a convenient range line and the points thus found connected to the point at which the lines cross the central line of the tangent scale chart. It is seen that this point is not the zero range line on the tangent scale chart, but a point where the value of "a" in the above formula is zero for all angles, or in other words where $\left(8 + \frac{R}{20}\right)$ is equal to R.

Under the tangent scale chart are two centering pins (14) intended to drop on each side of the station arm and so place the center line of the tangent scale chart directly over the fiducial edge of that arm. These pins are held down by a spring so that in the case where the gun arm is over the station arm at that position the pin that strikes on the top of the gun arm will be lifted by the gun arm and so not interfere with the setting.

Near the outer edges of the tangent scale chart board are two supports (15) intended to rest on the plotting board and so provide a support under each end of the tangent scale

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4 INCHES
DEV. DIV., T. S., C.A.T.C.
31 JULY, 1919

DRAWING NO. 1

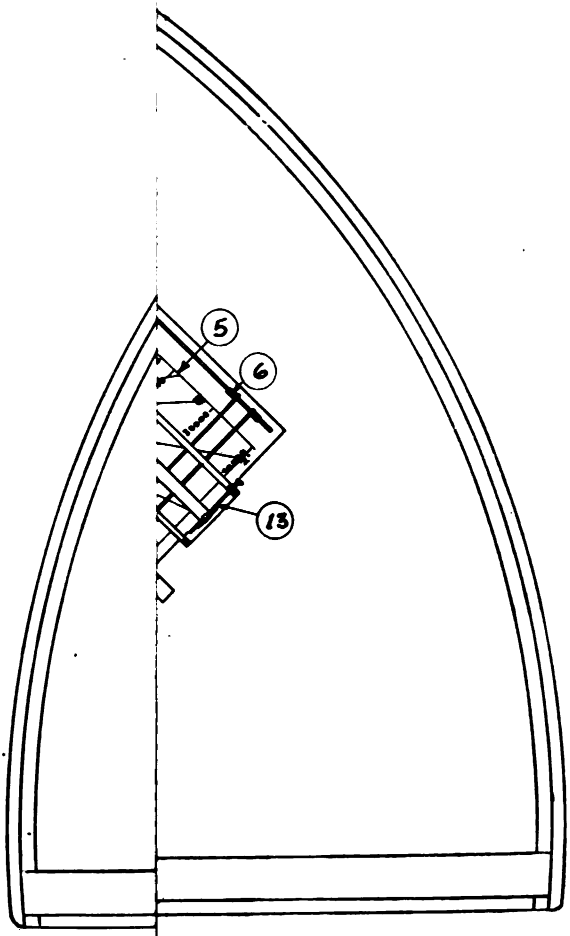

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chart. These supports are pivoted as shown so that they they can clear any arm in case of interference. Similar supports may be placed under the edges of the disc if necessary.

Pivoted in the center of the pin that holds the disc is a targ (16). This targ is free to turn so that the knife edge is always under the exact center of the disc and so that it can be brought up to the intersection of the two station arms. This allows the center of the disc to be placed quickly and accurately over the target position.

ORIENTATION

The station block for observation station "A–2" is set for distance from the "A–1" station block on the base line arm, and the base line arm is oriented for the azimuth of the base line in exactly the same manner as is prescribed in instruction pamphelts and drill regulations for the orientation of a Battery or Fire Command base line on an ordinary Whistler Hearn plotting board, except that the scale used on this board is 1000 yards to the inch instead of 300 yards to the inch. The center of rotation of the sleeve (7) is set for the lateral displacement of the directing point of the fort right or left of the "A–1" observation station by setting the clamp (9) to a corresponding distance right or left on the base line arm. The longitudinal displacement is set by clamping the short arm (8) so as to hold the sleeve (7) to the front or rear of the base line arm to a distance corresponding to the longitudinal displacement of the directing point.

OPERATION

Assuming that the base line with Azimuth Instruments Model of 1910 in stations at "A–1" and "A–2" has been designated as the base line for the observation of fire for adjustment, the operation of the Deviation Computer would be as follows.

The observers at "A-1" and "A-2" would follow the target upon which fire is to be adjusted as in the case of ordinary horizontal base tracking.

The readers at "A-1" and "A-2" would read the azimuth to the target at the end of each fifteen second time interval and telephone the reading to the "A-1" and "A-2" arm setters on the Deviation Computer plotting board.

The "A-1" and "A-2" arm setters would set the arms so as to maintain the intersection indicating the position of the target but no plotting would be done at this time.

When firing begins the plotter would place the disc in the position shown by the dotted lines on Fig. 1., note the range on the "A-1" arm and set the "A-1" target distance marker. He would then place the tangent scale chart board in a similar position over the "A-2" arm and set the "A-2" target distance marker. He would continously check up on the positions of the target distance markers during the firing and change them whenever the range from the stations changes enough to make an appreciable change in the deviation plotted.

When a splash occurs the "A-1" and "A-2" observers would stop their instruments and each read the angular deviation of the point of impact as seen on the inner scale of his instrument. This would be read in hundredths of a degree right or left of the target.

These readings would be telephoned by the readers to the the "A-1" and "A-2" arm setters who would call "Splash" and leave their arms set at the last azimuth readings.

The plotter would bring the targ accurately to the intersection of the arms, place the tangent scale chart over the "A-1" arm and call for the "A-1" deviation.

The deviation would be called out by the "A-1" arm setter and the plotter would set the T-square blade by use of the micrometer head screw to the angle given, and then set the T-square so that it would intersect the diagonal line graduation at the point at which that line intersects the target distance marker for "A-1" and draw a line on the disc along the edge of the T-square blade. This line represents on the disc the exact line along which the "A-1" observer saw the splash.

The same operation is carried out with the tangent scale chart centered over the "A-2" arm and using the angular deviation sent in from the "A-2" station.

The intersection of the two lines on the disc represents the position of the splash with respect to the target at the center of the disc. The yards "Over" or "Short" and "Right" or "Left" as referred to the directing point of the fort is then read directly on the quadrille scale of the disc.

As soon as a splash is plotted the tracking of the target is resumed by the observers and the plotting detail is ready for the next splash.

The whole operation of plotting and measuring the deviation of a splash from a target can be done in a few seconds so that continous adjustment of fire on a moving target is possible.

By adjusting the board for the computatuons of deviations as referred to a reference point for the fort or fire command, one board can adjust fire for several batteries. The battery commanders would then receive the deviations as computed and each correct the values received in order to refer them to his battery–target line. If several batteries are adjusting on the same target at the same time it would be necessary to allow just sufficient time between the shots from different batteries so that the splashes would not be confused by the observers. The observers need not know what batteries are firing as long as the fort or fire commander knows the order in which the splashes occur so that he may send the deviations in each case to the proper battery commander.

When firing begins the plotter would place the disc in the position shown by the dotted lines on Fig. 1., note the range on the "A-1" arm and set the "A-1" target distance marker. He would then place the tangent scale chart board in a similar position over the "A-2" arm and set the "A-2" target distance marker. He would continously check up on the positions of the target distance markers during the firing and change them whenever the range from the stations changes enough to make an appreciable change in the deviation plotted.

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Practical Interior Ballistics

By Harold G. Manning, SB. LLM. MPL.

PART I.

Introductory Report of the Interior Ballistics Division, Aberdeen Proving Ground*

INTRODUCTION

1. Outside of the problem of increasing the size, destructive capacity, and traveling power of modern projectiles, the most important subject in Artillery design and practice today, is believed to be the problem of *increasing the accuracy of gun fire.*

To this subject, much time and thought has been given by artillery experts throughout the world, especially during the recent war. Among the various factors investigated, which will cause inaccurate shooting if not taken into account, are the following:

(1) Air Density.
(2) Wind velocity and direction.
(3) Rotation of the earth.
(4) Action of the Gun—Variable jump, etc.
(5) Weight and shape of the projectile.
(6) Velocity of Projectile as it leaves the gun.

It has been found in practice that some of these factors are quite variable, not only from day to day, but even from shot to shot.

Most of the time and thought of the experts has been put upon methods of reducing the errors in gunfire caused by the first five factors of the above list, and during the World War, many remarkable improvements in such methods have been made and adopted, while the study of the causes of *velocity variations* appears to have been neglected.

The principal cause of velocity variation is variation in the *conditions of loading*, or in the so-called "interior ballistics" of the Cannon. In practice, great precautions are exercised to keep these conditions constant, but despite all precautions, large errors are frequently introduced in the desired point of impact, due solely to "dispersion" in velocity.

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As reduction of velocity variation is essential to accuracy in gunfire, as well as reduction of the errors due to the first five factors, it was deemed desirable to investigate the subject and a division of "Interior Ballistics" was therefore established in the Range Firing Section of the Army Proving Grounds, at Aberdeen, Md. The writer, then a 2nd Lieut. was assigned to the task and was placed in charge of the new division, with Sergt. Irwin Roman acting as principal assistant. The purpose of this report is to give an account of the methods employed in the investigation which has been made by the division, to give the conclusions reached, and to indicate the direction in which further research is desirable.

While this investigation was made primarily to insure accurate firings for use in *range table* preparation, the results are believed to be of *general* application.

THE PROBLEM

2. The broad subject of interior ballistics divides itself naturally into three parts:

(a) The study of the *design* of new guns, projectiles, and powder.
(b) The accurate estimation of powder *charges* for different ballistic conditions, in *existing guns.*
(c) The study of the effects upon velocity and pressure, in existing guns, of small variations in the established standard firing conditions.

After a preliminary study of the situation, it was realized that the general subject of interior ballistics was exceedingly complex; in fact, it is considered by some to be even more complex than exterior ballistics. It was accordingly decided to pass over the questions of design and accurate estimation of powder charges, and to *specialize* on the study of the *changes* in muzzle *velocity* (and also changes in maximum *pressure*) produced by small changes in the conditions of loading.

Among the immediate labors which it was decided to undertake were the following:

1. To investigate all *causes of dispersion* in muzzle velocity and maximum pressure.
2. To collect experimental data, showing the *actual* effects

upon *velocity* and *pressure*, of known variations in firing conditions.

3. To investigate existing mathematical methods of estimating velocity and pressure, and from these to select simple, rapid formulas which would predict "differential" *changes* with sufficient accuracy for all practical purposes.
4. To systematize and improve methods for velocity *corrections*, applicable to Range Table work.
5. To investigate a method for roughly *estimating charges* to give any specified velocity and pressure for conditions not far from normal.

DESCRIPTION OF WORK

3. Preliminary Study.—Among the thirty different factors which were found to cause dispersion in velocity*, *three* were chosen for preliminary investigation, namely weight of *powder charge*, volume of powder *chamber*, and weight of *projectile*.

4. Existing Formulas.-Among the types of formulas which were in use for the prediction of muzzle velocity and pressure in guns, the best known are those of LeDuc, Gossot-Liouville, and Sarrau.

5. After a preliminary trial, it was decided to adopt the Sarrau* type of formula for velocity and pressure estimation, on account of its simplicity and sufficient reliability for all practical purposes.

6. Determination of Coefficients.-A method was soon found by which the constants or coefficients of the Sarrau formulas should be quickly and accurately determined.*

7. Collection of Firing Data—An examination was next made of all available velocity and pressure records at the proving ground for all firings in which *any* of the conditions of loading had been varied. A systematic collection was made of all such data.

8. While the investigation was made primarily to determine the coefficients for powder charge, chamber volume, and weight of projectile, note was made of all accurate data found, relating to *other* possible factors causing variations and pressure (such as Temperature; Erosion, etc). Those other factors will be considered later. The primary coefficients are six in number as follows:

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*See part II of this series.

α- % increase in velocity for 1% increase in weight of charge.
β- % increase in velocity for 1% decrease in chamber volume.
n- % increase in velocity for 1% decrease in weight of projectile.
α_1- % increase in pressure for 1% increase in weight of charge.
β_1- % increase in pressure for 1% decrease in chamber volume.
n_1- % increase in pressure for 1% increase in weight of projectile.

The above coefficients were empirically determined for all cannon where firing data was available, by the method mentioned in paragraph 6.

The values of these six coefficients, for some of the more important cannon, were then tabulated, as shown in Table I.

Subsequently all record sheets of range firing programs at the proving ground were submitted as a matter of routine to the Interior Ballistics Division for accurate estimation of the velocity of all shots fired for range, by means of Table I. After this estimation, the record sheets were turned over to the Exterior Ballistics Division for the computation of range tables, account being taken of all six factors of paragraph 1, above, in the usual manner.

9. *Estimation of charges.*—It will be noted that a nearly complete set of experimental values of α and α_1 are included in Table I. Hence, it was now possible, in nearly all cannon, to estimate roughly powder charges which would give any desired velocity or pressure (provided that the new conditions do not vary too much from the standard for which the coefficients were determined, and that the same character of powder is used).

10. A chart based on values of 0.66 for α and of 1.6 for α_1 was prepared for the 75 mm. gun (see chart A). It is believed that this chart and others of this nature will prove of considerable value to proof officers for rough calculations.

The use of this chart is illustrated with the following example:

Assuming that 22 oz. of a certain powder gives a velocity of 1750 f.s. and a maximum pressure of 33,000 lbs. sq. in., in the 75 mm. gun with a certain projectile; what charge will be necessary to give 2000 f.s. and what will be the resulting pressure? The answers may be read directly from the chart, and it is found that the charge will be 27 oz. and the maximum pressure will be 46,000 lbs. sq. in. This pressure is excessive, hence in this case 27 oz. of the given powder cannot be used. A slower powder, as for example, one with a greater web thickness, would be required in the above instance. In case a new powder is tried, the velocity and pressure lines on the chart will be moved parallel to the original lines, but the same chart may still be used.

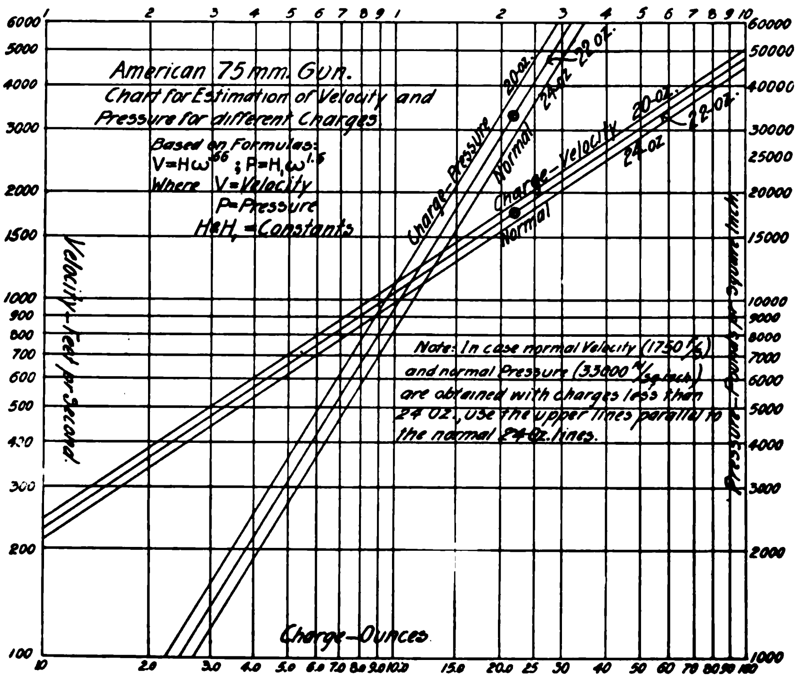


CHART A. 3467

Similar charts can easily be made for other cannon, such as the 155 G. P. F., 8-inch howitzer, 9.2-inch guns, etc., but as the use of all these charts is exactly the same, it is thought that one illustration will be sufficient.

11. *Limitations of Table I*—The actual use of Table I for velocity estimation in a large number of range firing programs demonstrated that the table was very valuable. However, although it was a big advance over the former system, (when the coefficients were assumed to be identical for all cannon),

in many cases the coefficients were somewhat *inaccurate* due to poor firing data, and the table was lacking in values of β and n, except in a few instances. Furthermore, the values of all the coefficients determined experimentally under *standard* conditions of loading, were found to vary somewhat from those determined for ballistic conditions other than standard, even in the same gun.

To complete the table and eliminate the above objections, two plans were available:

(1) To make special experimental firings for *all possible* conditions of loading in each gun. Obviously, this method would be prohibitive owing to the difficulties and cost attending the experiments.

(2) To complete the table and provide for conditions other than standard by *theoretical calculation.*

The latter of the two plans was considered most feasible, and it was therefore decided to develop a method for computing the *coefficients* from a theoretical *basis,* with as little recourse to experimental firings as possible.

12. For this purpose, the formulas of LeDuc were selected because they were believed to be the most reliable of the many formulas available, and also because they had been adopted as the standard for the Naval Proving Ground. The details of this theoretical investigation were worked out by Sergt. Roman, and the results will be described in full in a subsequent article of this series. By means of this theoretical method, not only were the missing coefficients supplied and provision made for the changes from standard conditions, but a check was obtained for the coefficients already determined experimentally. Furthermore, it is now possible quickly to compute the value of a coefficient for any *arbitrary* set of firing conditions in any cannon. The agreement between theory and experiment is quite good as will be seen by comparing the theoretical coefficients in Table II with the corresponding coefficients in Table I. In only a few instances in some of the guns of large caliber, is the check poor. For example, in the guns above the 10-inch, the theoretical values of a and a_1 are consistently lower than the values determined from the few experimental firings available. It is accordingly suggested that in the larger cannon the theoretical values be used with reserve until better experimental verification is obtained, especially when accident might occur by an error in

the coefficients. In most cannon the experimental and theoretical results are in excellent agreement.

While it cannot be said that the theoretical method of computing the coefficients (presented in Sergeant Roman's Article of this series)completely solves the problem, it is believed that it is the best method now available, and the results are believed to be quite reliable. As far as is known, it is the first rational attempt to combine the simplicity of Sarrau's formula with the accuracy of a more complicated method.

13. *Effect of Temperature of Powder*—The effect of the temperature of the powder on velocity and pressure was next considered. A simple empirical formula was discovered, which is applicable both to velocity and pressure corrections. The constants for use in this formula are found to vary greatly in different guns, and the correction tables given in Ordnance Pamphlet 1872 and Artillery Circular M are shown to be inaccurate. (This matter will be fully discussed in a subsequent article of this series.)

14. *Effect of Erosion*—The loss of velocity and pressure due to erosion was next studied and three different types of formulas were found, either of which can be used to account for this loss. The first of these formulas is based on the number of "equivalent service" rounds in the gun; the second is based on the amount of the enlargement of the bore at a distance of one inch from the beginning of rifling; and the third is based on the change in seating produced by the erosion. (To be fully discussed in another subsequent article of this series).

15. *Miscellaneous Problems*—Firing data on certain *minor factors*, influencing the muzzle velocity and the maximum pressure, were also examined by the Interior Ballistics Division and will be discussed in an article (to be published in a later issue of the Journal) under the following heads:

(1) Igniters.
(2) Removal of the lip from the rotating band.
(3) Boat-tailing.
(4) Angle of elevation.
(5) Containers.
(6) Crimping.
(7) Obturators.

16. *Summary and Conclusions.*—The purposes for which the Interior Ballistics Division was established, and a history of the progress of the work done have been discussed in this introductory article.

It is believed that the results of this investigation will enable an artillery officer or gunner to materially improve his accuracy, not only at target practice, but on the field of battle and in naval actions.

TABLE I

COEFFICIENTS FOR INTERIOR BALLISTICS

(EXPERIMENTALLY DETERMINED)

Note—The values given are for standard firing conditions.

α = % *increase* in *velocity* caused by 1% *increase* in *powder charge.*

α_1 = % *increase* in *maximum pressure* caused by 1% *increase* in *powder charge.*

β = % *decrease* in *velocity* caused by 1% *increase* in *chamber volume.*

β_1 = % *decrease* in *maximum pressure* caused by 1% *increase* in *chamber volume.*

n = % *decrease* in *velocity* caused by 1% *increase* in *weight* of *projectile.*

n_1 = % *increase* in *maximum pressure* caused by 1% *increase* in *weight* of *projectile.*

Table I continued

Cannon	Model	Velocity Coefficients			Pressure Coefficients		
		α	β	n	α_1	β_1	n_1
37mm	1916	.7	–	–	2.8*	–	–
2.24″S.C.	1910	.80*	–	–	1.0*	–	–
2.95mt.	1901	.75*	–	–	1.7*	–	–
75mm	1916	.70	.20	.33	1.4	.42	–
3″F.G.	1905	.79	–	–	1.6*	–	–
3″AA	1918	.98*	–	–	1.8	–	–
3″Stokes T. M.	. .	.55	–	–	–	–	–
3.2″ G	1895	.68*	–	–	1.2*	–	–
3.8″H	1913	.68	–	–	1.2	–	–
4.7″G	1906	.60	–	.24	1.6	–	.14
4.7″H	1912	.70	–	–	1.0	–	–
4.7″H	Panama	.68	–	–	1.3	–	–
5″G	1897	.97*	–	–	1.9*	–	–
6″H	1908	.62*	–	–	1.3*	–	–
6″S. C.	1900	.70	–	–	1.5	–	–
6″Stokes T. M.	–	.68	–	–	–	–	–
155mm G	G.P.F.	.77	.25	–	2.0*	.88	–
155mmH	Schn.	.72	.21	–	1.4	1.1	–
8″RR	1888	.68	–	.30	1.6	–	.35
8″H	Mk.VI	.60	–	–	1.2	–	–
9.2″H	Mk II	.62	–	–	1.2	–	–
240mmH	1918	.78	–	–	1.3	–	–
12″M	1890	.73	–	–	1.2	–	–
14″Naval	Mk.IV	1.16*	–	–	1.9*	–	–
14″G	1907	.99*large chamber			2.1*	–	–
14″G	1907 MKI	1.08*small chamber			2.8*	–	–
16″Rifle	1895	1.16*	–	–	2.5*	–	–
16″H	1918	1.08*	–	–	–	–	–

* doubtful accuracy.

Table II

Theoretical Coefficients for Interior Ballistics

Note-the values in this table are for standard conditions

Cannon	Model	Velocity Coefficients			Pressure Coefficients		
		Charge α	Chamber Volume β	Weight of Projectile n	Charge α_1	Chamber Volume β_1	Weight of Progectile n_1
37mm	1906	.82	.58	.24	1.8	1.5	.67
75mm	All	.71	.38	.33	1.7	1.3	”
3″F.G.	1905	.74	.39	.36	1.9	1.6	”
3″A.A.	1917	.66	.29	.37	1.6	1.3	”
3″A.A.	1918	.72	.62	.25	1.9	1.6	”
4.7″Gun	1906	.79	.44	.35	2.1	1.8	”
4.7″Pan.H.	1913	.65	.27	.38	1.5	1.2	”
4.7 How	1912	.76	.53	.23	1.6	1.3	”
6″ How	1908	.65	.30	.35	1.5	1.2	”
6″W.Mt.	1905	.64	.28	.36	1.5	1.1	”
6″S.C.	1900 1908	.76	.42	.34	1.9	1.5	”
155 Gun	1918	.70	.36	.35	1.7	1.3	”
155 How	1918	.70	.36	.34	1.7	1.3	”
8″ RR.	1888	.75	.47	.29	1.7	1.3	”
8″ How	1917	.62	.19	.43	1.5	1.2	”
240 How	1918	.65	.25	.40	1.6	1.3	”
10″Gun	1895	.82	.56	.26	1.8	1.5	”
12″Gun	1895	.81	.53	.28	1.8	1.5	”
14″Gun	1907	.73	.38	.35	1.8	1.5	”
14″Gun	1919	.76	.45	.31	1.8	1.4	”
16″Gun	1895	.81	.54	.27	1.8	1.5	”
16″Gun	ModelB	.76	.46	.30	1.8	1.4	”
16″How	1918	.71	.35	.36	1.8	1.4	”
16″How	1918	.71	.35	.36	1.8	1.4	”

PART II

EMPIRICAL METHODS FOR REDUCING DISPERSION IN VELOCITY

1. Part I of this article contained a general report of an investigation conducted by the Interior Ballistics Division of the Aberdeen Proving Ground. This part is the second of the series and deals with the causes of *dispersion in velocity* and some of the methods which have been developed by the Interior Ballistics Division for reducing such dispersion to the minimum.

In connection with the vital problem of improving accuracy of gun fire, the importance of securing uniform velocities of projectiles as they leave the cannon will be evident when it is considered that errors in velocity may introduce large deviations in the point of impact of the projectile. The dispersion in velocity actually obtained varies considerably with firing conditions, and in some cases is as great as 1%. The purpose of this part is to discuss the causes of dispersion in velocity and the methods of allowing for them. Errors due to personnel have been reduced to a minimum in American artillery practice and are much smaller than the errors in the "matériel." Such "personnel" errors are to a large extent unavoidable and will not be considered here, this report being confined to a discussion of "preventable" errors in "*matériel.*"

EFFECT OF VARIATION IN VELOCITY UPON RANGE

2. In order to appreciate fully the magnitude of the errors in range produced by variations in muzzle velocity the following data are given for six different guns now in use:

TABLE III.

Gun	Error in range produced by an error in velocity of 10 f/s at maximum range ΔRv	Expected Δ R due to all causes-meters	Max. Range Meters	Standard Velocity f/s
75 M/M (French)	23 Meters	53	7700	1750
4.7	36 "	210a	11200	2050
6″	55 "	80	16500	2600
155 M/M	49 "	130	14000	2410
8″	72 "	105	19300	2600
14″ Naval	239 "	350b	43500	3000

a-large dispersion due to poor design of rotating band.

b-rough estimate.

It is seen from the above table that the dispersion which is introduced by a variation in initial velocity, even as small as 10 f/s. is quite large. In many cases variations in velocity undoubtedly are the largest cause of errors in range.

Uniformity in initial velocity is especially desirable at the lower angles of elevation, as under these circumstances the percentage change in range is greatest for an equal error in velocity. The following computations for the 155 mm. Howitzer will illustrate this point. These computations were made from data based on firings at the Aberdeen Proving Ground.

TABLE IV

155 mm. Howitzer—30° Elevation

Dispersion in Range Due to Variation in Velocity

Zone	Velocity f/s	Range Meters	Change in Range due to 1% change in velocity.	%change in Range due to 1% change in Vel. Δ Rv	Mean % deviation in range due to all causes Δ R.
1	655	3125	61 meters	1.9	.95
2	730	3887	68	1.74	.78
3	795	4513	78	1.73	.71
4	900	5554	88	1.59	.57
5	1065	5469*	67*	1.23	.38
6	1310	8598	72	.84	.21
7	1430	9262	77	.83	.19

* 20°Elevation

Note: The mean deviation in velocity may run as high as 1% in practice, and is generally greater than .25%

This table clearly shows that the comparative effect of velocity variations is greatest at the lowest elevations.

3. Causes of Dispersion in Range

The four main causes of dispersion in range are:

(a) Variations in atmospheric conditions.
(b) Variations in action of gun: variable jump, etc.
(c) Variations in ballistic coefficient.
(d) Variations in muzzle velocity.

4. General Methods of Reducing Dispersion

Variations in atmospheric conditions evidently cannot be reduced. There are, however, several methods which may be employed to reduce the *effects* of all variations and the magnitude of the last three variations :

(a) Improving the design of the gun, projectile, and powder.
(b) Maintaining constant firing conditions.
(c) Making corrections in elevations for all known variations from standard conditions.

5. CAUSES OF DISPERSION IN VELOCITY

There are many causes of dispersion in velocity which have been studied. The following list includes all of the possible causes known at the Aberdeen Proving Ground.

Powder

1. Variable powder magazine temperature.
2. Variation of powder temperature due to variable time in guns before firing.
3. Hang fires.
4. Variation in Erosion.
5. Inequalities of powder, i.e.-non-uniformity, unequal deterioration, loss of mositure, and volatiles.
6. Unconsumed powder. (See reference, Par. 442 Gunnery Instructions, 1913).
7. Variation in burning at reduced pressure.
8. Variation of ignition charge.
9. Variation of distribution of igniter (Little effect).
10. Improper powder (if wrongly designed, excessive pressures in some parts of the bore might result, but if velocity is O.K. no effect in range).
11. Improper assembling.
12. Unequal blending.
13. Variation in density or in dampness (Powder tanks should be airtight. If not powder will get damp. See Par. 433, Gunnery Instructions 1913).
14. Variation in weight of charge.

Shell

15. Variation of weight of projectile.
16. Variation in hardness, width and shape of rotating bands.
17. Stripping of bands (does not often occur).
18. Variation in centering axis of shell with gun (probably no effect).
19. Variation in diameter of bourrelet (Little effect).

20. Boat-tailing.
21. Use of lips, (thin layer flares out).

Cannon

22. Variation in temperature of gun due to heating, i.e.—unequal expansion of bore and chamber, causing effects similar to erosion (low magnitude.)
23. Variation in rifling.
24. Variation in chamber capacity.
25. Wear on rotating bands making seating unreliable. (Wear on copper band and on steel seat from "drill" is of no effect). Wear on seat from firing can be taken care of by correction formulae which will give the loss in I. V.
26. Elevation of gun.
27. Lubrication of bore.

Other Causes

28. Use of improper containers, variation in silk of bags. (Note: Pyralin containers give poorer uniformity than silk).
29. Variation in Obturators.
30. Variation in Crimping of Cartridge cases (when fixed ammunition is used).

6. METHODS OF IMPROVING UNIFORMITY IN VELOCITY

Of the three general methods of reducing dispersion outlined above, (in Par. 4) only the method which consists of making all known corrections for variations from standard conditions will be considered here. Improvements in design of the matériel and in means for maintaining constant firing conditions are beyond the scope of this article.

In order to make intelligent corrections to the angle of elevation to compensate for variations in the muzzle velocity, all modern range tables are provided with columns showing the error in range corresponding to a unit deviation in velocity. Then if the velocity is known accurately, the range can be corrected by means of these columns.

The problem therefore reduces itself to a study of methods for estimating the actual muzzle velocity of the projectile for any firing conditions. In order to estimate this actual muzzle velocity accurately, a systematic study was made by the Interior Ballistics Division of velocity correction formulae, and these formulae were tested by applying them to nearly all the firing records available. Coefficients to be used in the correction formulae have been determined for a large number of guns, howitzers, and mortars and by the use of these formulae, in estimating muzzle velocities, it is believed that a firing officer can materially increase the consistency of observed ranges with expectations. Among the various factors influencing velocity the following have been reduced to a mathematical basis:

(a) Weight of projectile.
(b) Weight of charge.
(c) Chamber volume.
(d) Density of powder.
(e) Temperature of Powder.
(f) Travel of Projectile in Gun.
(g) Erosion.

7. Discussion of Old Methods And Formulae

Many formulae have been proposed for determining the *muzzle velocity* of a projectile and the maximum or gage *pressure* in the cannon. Nearly all of these are quite complex and the work of computation required in making use of them for routine differential corrections is very great. In this investigation the various formulae in the literature on interior ballistics were examined not alone for their accuracy, but also for their simplicity, and convenience in use. It was desired if possible to find a simple formula which would be quite accurate for small variations and reasonably accurate for large variations from standard conditions.

The most common variations are met with in:

(a) The weight of powder,
(b) The chamber volume, and
(c) The weight of projectile.

Variations in the other factors are of course important but in the preliminary investigation were assumed to be maintained constant.

8. *Velocity Formulae Adopted*: Among the formulae which have been proposed for the muzzle velocity of a projectile, the most wellknown are those of LeDuc, Goussot, Liouville, and Sarrau. The Sarrau formula, which was originally used for black powder appears to be applicable also to present day smokeless powder. It was found from a preliminary examination of data for twenty-five different guns at

the Aberdeen Proving Grounds, that the Sarrau Equation gave quite accurate results provided the constants were empirically determined for each gun. As this formula is much simpler and easier to apply than the others it was decided to adopt it provisionally for use in velocity corrections.

The abundance of firing data available at the Aberdeen Proving Ground was carefully studied, and the results were subsequently put into formulae, curves, and tables, convenient for rapid computation. The constants or coefficients involved in these formulae were accurately determined for each gun.

(a) Velocity correction for variations from standard weight of projectile.

In the form most convenient for our use, the Sarrau formula is:

$$V_1 = V_0 \frac{(p_0)^n}{p_1}$$

where V_1 and V_0 are the corrected and observed velocities respectively and p_1, and p_0 are the actual and standard weights of projectile.

When the variations in weight do not exceed 10% of the standard, this formula may be thrown into the approximate form convenient for slide rule use:

$$dV = -nV\frac{dp}{p}$$

where dp and dV represent the change in weight of projectile and the corresponding velocity correction, respectively. This approximate formula gives the velocity correction with sufficient exactness in nearly all cases, as in practice weight variations have been found to be well within 5% of the standard weight. As stated above and as is supported by numerous experiments in Aberdeen, as well as in France, the accuracy of this formula may be depended upon up to 10% variations. In the 75mm gun for example, if $n = 1/3$, a variation of one ounce in the 12-lb. projectile will introduce a variation in muzzle velocity of 3 f/s, at the service charge. In other words an increase in weight of 1% will decrease the velocity by 1/3%.

(b) Correction for weight of charge.

A formula similar to the one appearing under (a) has consistently given sufficiently accurate results for changes in propellant charge. In fact this accuracy has been such as to warrant the use of the formula for purposes of prediction of charges to be used to acquire certain other velocities, when the velocity for one charge is known, (for a given type and lot of powder). In the approximate form for convenient use, this formula may be written:

$$dV = \alpha V \frac{d\omega}{\omega}$$

where ω and $d\omega$ are charge and change in charge respectively and α is a constant.

Example: In the 75 mm. gun, if $\alpha = .66$, at the velocity of 1750 f/s. and weight of charge of 21-7/8 oz. the change in velocity for one ounce change in weight of powder will be 52.8 f/s.

(c) Correction for chamber volume.

Changes in chamber volume, principally due to changes in the seating of the projectile, are most commonly met with in *unfixed* ammunition. However, due to differences in the rear of projectiles of different types, compensation is necessary for *fixed* as well as unfixed ammunition.

The formula

$$dV = -\beta V \frac{dS}{S}$$

where dS and S are the change in chamber volume, and the standard chamber volume, respectively, gives the correction for variations in chamber volume.

Example: In the 75 mm. gun, when $\beta = .2$ under standard conditions, a change in chamber volume of 1 cu. in. will introduce a change of 4.1 f/s. in velocity.(Standard chamber volume 85.5 cu. in).

COMBINED FORMULAE

9. The formulae given in the last 3 paragraphs may be combined into a single approximate formula* as follows:

$$dV = \alpha V \frac{d\omega}{\omega} \quad - \beta V \frac{dS}{S} \quad - nV \frac{dP}{p}$$ or more accurately:

---

* In case the variations from standard conditions are small, the approximate formulae may be used in practice with sufficient accuracy (e.g. at 2000 f/s, even with a variation of 10% in powder charge, the error in using this formula will be only about 2 f/s.

$$V = \frac{H\omega^a}{S\beta p^n}$$

where H, β, and n are constants, and V = Velocity, ω = weight of powder charge, S = chamber volume and P = weight of projectile.

10. *Pressure Correction Formulae*: It has been found that equations similar to the velocity correction formulae can be used to correct pressures as well. The corresponding pressure formulae are

$$dP = P\left(a_1 \frac{d\omega}{\omega} - \beta_1 \frac{dS}{S} + n_1 \frac{dp}{P}\right)$$

or $P = \frac{H\omega^{a_1}p^{n_1}}{S^{\beta}{}_1}$ where H, a_1, β_1, and n_1 are constants,

P = pressure,
ω = weight of powder charge,
S = chamber volume, and
p = wt. of projectile.

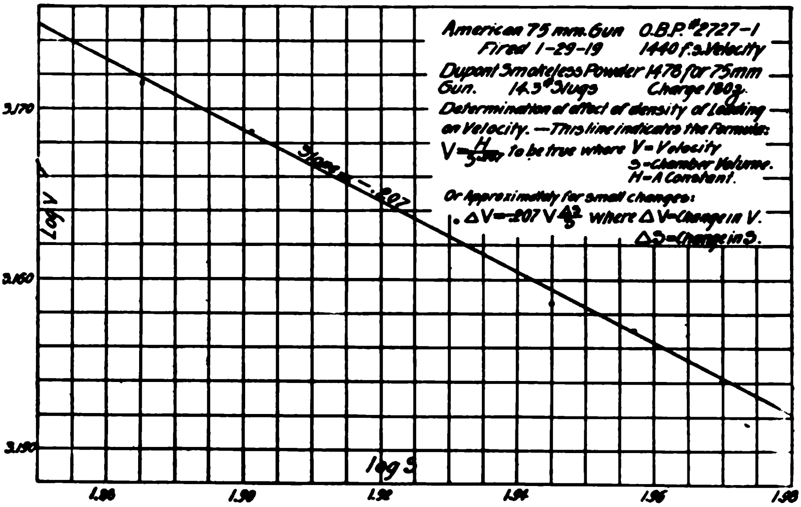


FIG. 1.

DIFFERENCE FORMULAE

11. If desired, the following type of accurate difference formula may be used instead of the equations given above.

$V_1 - V_0 = V_0\frac{(\omega_1^a - \omega_0^a)}{\omega_0^a}$ (this formula is for powder charge variations).

In order to use any of the above formulae it is first necessary to know accurately the value of the constants a, a_1, β, β_1, n, n_1.

Tables I and II given in Part I of this series show the value of these constants as empirically and theoretically determined from the best data now available.

12.*Method of obtaining constants for formulae.* In general, to obtain the value of r in the general formula $y = HX^r$ from experimental data two methods are avilable. These are as follows:

(a) Use the equation,
$$r = \frac{\log \frac{y_1}{y_0},}{\log \frac{x_1}{x_0}}$$

or (b) Plot *log x* against *log y* on a chart. The slope of the straight line which best represents the plotted points will give the value of r desired.

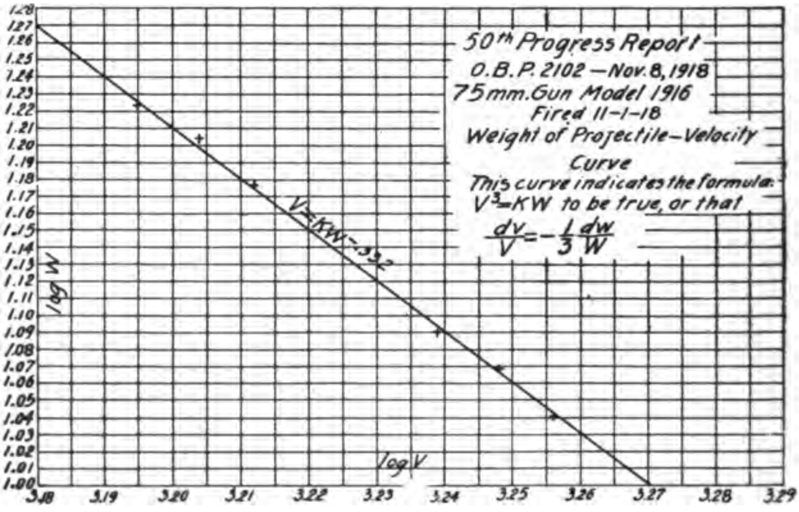


FIG. 2.

The latter method was the one used in nearly all cases in this investigation. Theoretically, all of the plotted points should be on a straight line. Graphs are attached (Figures 1-6) which illustrate this method (b), and it will be seen from the graphs that the experimental data agrees remarkably well with the theory.

Illustration of the use of the Accurate Formulae

13. In a 155 mm. Howitzer the velocity of shrapnel in zone 1 with powder charge of 2.28 lbs. was 661 f/s., What velocity would the same projectile (weight 95 lbs.) have in

zone 6, powder charge 6.70 lbs. Chamber volume 425 cu. in.? $a=.64$. By the Sarrau formula the calculation is simple, i.e.

$$V_1=661\left(\frac{6.70}{2.28}\right)^{.64}=1318 \text{ f/s.}$$

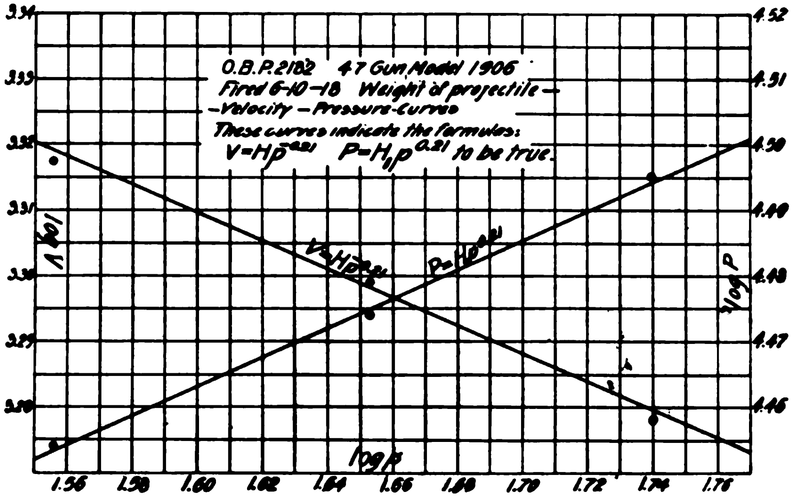


FIG. 3.

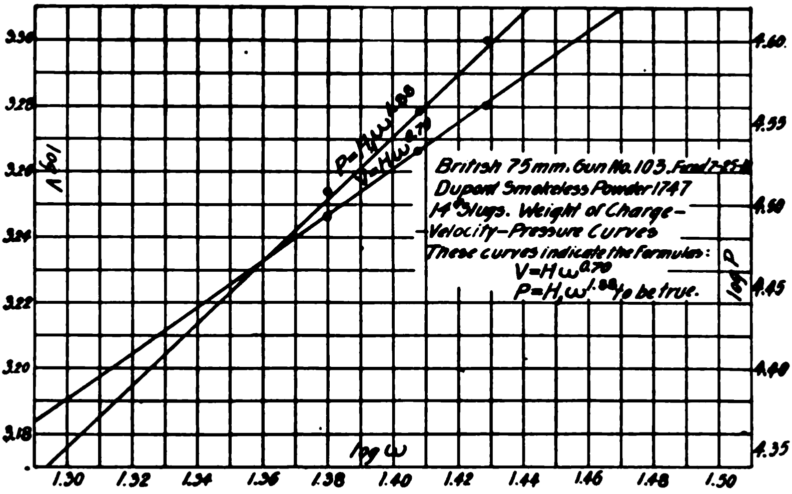


FIG. 4.

The actual value observed was 1314 f/s. By the LeDuc method, the calculation is quite complicated and time-consuming, and the value obtained is 1310 f/s.

Attention is called to the chart method given in Part I by which estimation of velocity, and pressure for different charges may be made graphically.

EFFECTS OF TEMPERATURE AND DENSITY OF POWDER, EROSION, AND OTHER FACTORS

14. These matters were briefly discussed in Part I and will be discussed more fully in subsequent parts. They will not therefore be taken up here.

VELOCITY MEASUREMENTS FOR RANGE TABLES

15. The principal use of the formulae presented in this and the following articles of this series is in the actual firing of cannon at targets, either on the battlefield, in naval actions, or in practice. Another exceedingly important application is in the preparation of accurate range tables to be subsequently used for the control of artillery fire. In preparing range tables it is customary to fire a series of shots at different angles of elevation and determine the actual range of each shot. These actual ranges are then corrected to *standard* "range table" conditions, compensation being made for air density, rotation of the earth, action of the gun, weight and shape of projectile, and *velocity*.

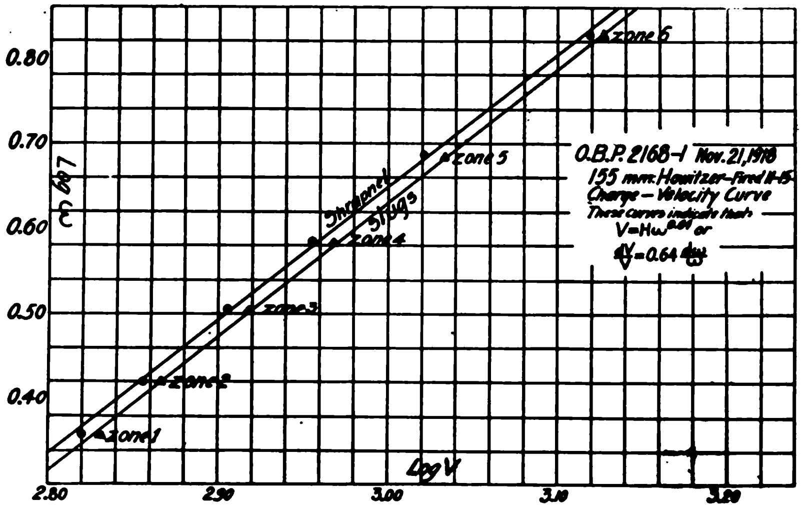


FIG. 5.

In range table firing, the importance of securing accurate velocity *measurements* cannot be overemphasized. Attention is called to the last column of Table V.

TABLE V.
Miscellaneous Data For Interior Ballistics

Cannon	Standard Velocity	Maximum Range	Change in R for vel. change of 10 f/s at max. range d R
75mm.	1750 ft. per sec.	8000 meters	23 meters
4.7" Gun.	2050	11200	36
6" Gun Mod. 1905	2600	16400	55
155 mm. How.	1420	10000	57
155 mm. Gun	2410	16000	59
8" How.	1300	9300	68
8" Gun	2600	18400 (40°)	84
14" Gun (Naval)	3000	43500	239

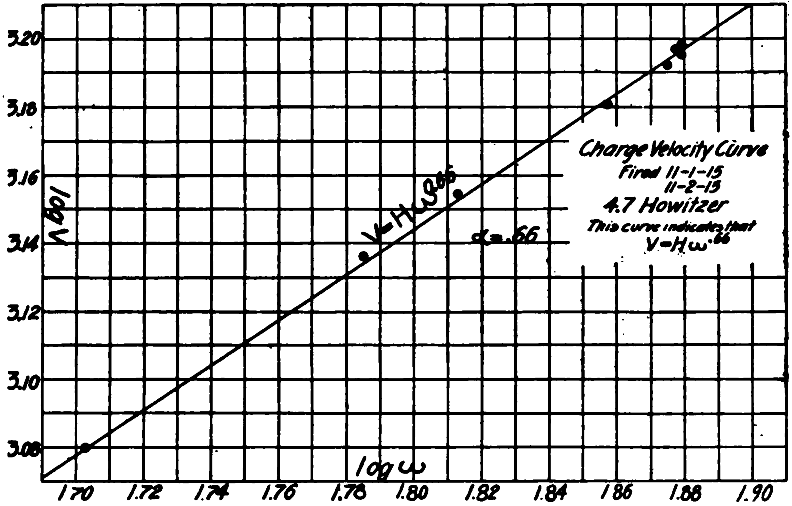


FIG. 6.

It will be noticed in the case of the 155 Howitzer, for example, that at maximum range, a change of velocity of only 10 f/s will produce an error in range of 57 meters. For larger guns the error is even greater in absolute magnitude. Its greatest relative importance in comparision with other errors, however, is at low elevations and low velocities.

It is evident therefore that if the original chronograph measurements of the velocity are not accurate, a range table based upon such measurements will be erroneous to a greater or less extent.

In using the formulas presented in this and the following parts, it is assumed that *accurate* velocity measurements have been made. A few remarks on the most frequent causes of errors in such measurements may however be of interest.

The two most frequent causes are:

(a) *Screen distances*, or errors in the measurement of the distance between the chronograph screens. During the firing of a program it is quite possible that the screens may become displaced due to wind, shock of discharge, blast of the gun, or by carelessness in raising and lowering the wires, which is done by hand between rounds, etc. The greatest care should be exercised to check screen distances at all times during a program where accurate velocities are required.

(b) *Correction to Muzzle*, or Errors in converting the velocity *measured between the screens* back to the desired value at the *muzzle* of the cannon. Such errors in the *correction to muzzle*, are generally due to variations in the "ballistic coefficient" and consequently in the value of (i). Such variations may be due to three reasons:

(1). Varying *stability* of the projectile, which causes erratic *wobbling*, and hence varying resistance to the air.

(2) Variation in the action of the *rotating band*, as for instance difference in fringing effect. (3) Variation in *ogive*, which is especially common in *slugs*.

Such variation in the ballistic coefficient is very difficult to determine, but it may often introduce errors of considerable magnitude into muzzle velocities.

PECULIAR ACTION OF THE FIRST ROUND

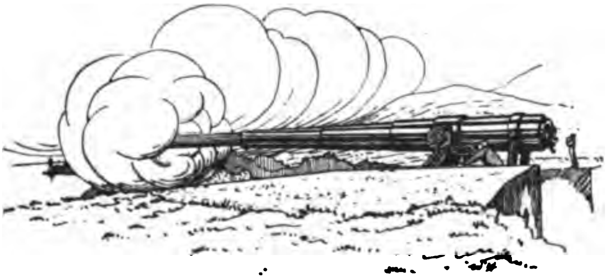
16. The practice at the Aberdeen Proving Ground in all Range firing work is to precede the velocity rounds of a program by a single shot to warm up the gun.

It has been found by long experience that when a gun has been standing idle for some time a considerable difference between the velocity for the first and the following rounds will occur. In most instances the velocity of the first shot will be smaller than that of the following rounds, but many cases have been observed where it is larger. The firing of a slug as a warming shot eliminates this trouble.

The exact reason for this peculiar action of the first round has never been discovered. It is believed however that cold guns absorb more than the usual amount of heat. Moreover, temperature strains are set up in the gun after it has been standing idle for some time. The excessive heat absorption and these initial strains probably contribute to the erratic performance of the first round.

SUMMARY

17. In this article the importance of the problem of increasing the accuracy of artillery fire by reducing the dispersion due to *matériel* has been brought out. It has been shown that variations in *velocity* play a large part in causing inaccuracy of gun-fire. Data are given illustrating the magnitude of the velocity effect on range dispersion and showing that this effect is greatest at *low angles* of elevation. Thirty causes of velocity variations are listed, and methods of reducing these variations are discussed. A list of seven of these causes for which corrections may be made mathematically is then presented, three of which are dealt with in this part, the other four being reserved for later parts in this series.



EDITORIAL REVIEWS

A WORD TO YOUNG OFFICERS

By reason of the rapid demobilization of the Army, unfortunately there will be slight opportunity for retaining as commissioned officers in the Coast Artillery those worthy men who, before the war, were noncommissioned offiicers and who, in response to the need of the great emergency accepted temporary commissions. The greater number of this class of temporary officers were men of long and honorable service as soldiers, before they were called upon to relinquish their certain status as noncommissioned officers, in behalf of the very uncertain opportunity held out to them with their temporary commissions. Their wide experience in the service, and their mature judgment rendered their service as officers invaluable to the Coast Artillery during the critical period of its effort in the war. The older officer of the Coast Artillery Corps who has known and respected these men both as soldiers and as officers, regrets the lack of future recognition for their work during the war, and deprecates the delay in the formulation of military policy by reason of which these officers are to suffer a very real injustice.

In many instancs, these temporary officers during the emergency have been successively promoted, so that many of them have been senior in grade to the youngsters who now, by very reason of their youth, with its concomitant of inexperience are able to retain their provisional commissions and will subsequently become permanent officers of the Coast Artillery. It is a curious reversal of normal military processes that the temporary officers who have exercised control over younger officers should now be reduced to non-commissioned status, in which position they will be required to ask advice and accept the dictum of young men who, until recently, were themselves looking for advice and authority from those who were then their seniors both in years and rank. It is perhaps natural that some of these old soldiers should return to subordinate positions with feelings not only of regret for the dignity and emoluments which they have lost, but as well with a certain doubt as to the treatment which will be accorded them by young officers who, however well intentioned, they know lack the experience to handle authority with the right combination of tact and firmness.

It is more important for the future than ever before that the Coast Artillery Corps, from top to bottom, should work together as a harmonious team. The older men now returning from commissioned to non-commissioned grades, have learned the lessons of loyalty and subordination. If the team is to to be a perfect team, not only must these old soldiers do their part, but so also must younger soldiers, the older officers of the Coast Artillery, and the younger officers to whom this suggestion is brought. In their relations with non-commissioned staff and non-commissioned officers, they must be most careful to clothe every act, word, and decision with tact, dignity, and consideration.

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VOCATIONAL TRAINING

At different times the spotlight of active interest is thrown first on one phase, and then on another, of the activities of the Army. Just now the beam has swung to Vocational Training, and holds it in a glare which leaves every other form of military effort somewhat in the shadow. It is interesting to watch the brilliant display, but it is also interesting to watch those who are both actors and audience—the officers of the army. Their reactions are various. Certain old-timers are overwhelmed, and feebly deprecate the pedagogic invasion as the latest evidence of the faddish degradation of what once was an army, and now is coming to be a young ladies' finishing school. To other officers the official support of Vocational Training gives "a grand and glorious feelin" for they vision a new army of inspired and perspiring youth, aroused to feverish zeal in handling rammer and shot-truck by the momentum of their ambition to master the cunning of bench and forge.

It is pertinent to observe that vocational training is not a new thing in the Coast Artillery. In the development of its own needed special personnel in the mechanical and electrical arts, the Corps long ago developed a practical and comprehensive system of instruction, which at the same time secured the required personnel to mann the complicated equipment of the Coast Artillery, and as well increased the potential earning capacity of the soldier when he should choose to return to civilian life.

From the experience of the Coast Artillery may be gleaned a principle upon which to guide the future development of vocational training. Vocational training should not be attempted to cover a wider range of trades and industries than the equipment and instructors can readily be made available for, at the post. This means that certain posts in a position to teach steam-fitting might undertake this instruction, while other posts—for instance, in the South—with no steam pipe on the reservation, and no use for one, would eliminate steam-fitting from their educational offerings. Courses in truck driving would be appropriate at Fort Williams—in reach of a network of roads, and obviously out of place at Fort Levett—on Cushing's Island.

The positive advantage to the Army in vocational training must be kept in mind, through its betterment of the soldier in stimulating his ambition and increasing his actual and potential usefulness as a man. The permanent value in the prosecution of the idea lies in tempering its application to the common sense limitations of each situation.

Finally, it must never be forgotten that the burden of an army on a commonwealth is justified by the army's effectiveness for national defense, and not by its success as a universal free trade-school or college.

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ANONYMOUS CONTRIBUTIONS

The value of an idea frequently rests more in the prestige of its author than in the originality of the suggestion. The Journal is in receipt of a communication which seems to contain the germs of a valuably fruitful idea, but in order to utilize the idea for the benefit of the Coast Artillery, correspondence with the author to secure further elucidation is necessary, and at the same time impossible, because the communication is unsigned.

If an idea is worth conceiving, and worth the labor of writing up, it is worth the backing of the author, and without that backing, it is necessarily useless to the Journal and to the Coast Artillery. As has been said before, and as the Coast Artillery must come to believe, the *pages of the* Journal *are available for free and open discussion of all matters affecting the Coast Artillery Corps.*

NEW METHODS TO SOLVE NEW PROBLEMS

In the coast defenses a great deal of important experimentation is constantly going on, looking to the betterment of fire control devices and inprovements in methods for the technical and tactical employment of seacoast armament. It is the mutual privilege and function of the coast defenses and of the JOURNAL to keep each other advised of developments and improvements in all of the many interests of the Coast Artillery, as these developments and improvements may come first to the notice of one or the other. One very significant change in thought in the handling of seacoast armament is the belief in some quarters that eventually graphic plotting will be done away with because of its unavoidable mechanical limitations in the problems of long range firing. If graphic plotting is to be done away with, it is worth the while of officers in the coast defenses to have a clue to the means that will displace graphic plotting, so that their professional zeal, which might otherwise be leading them to designs, modifications and improvements of predictors, time-range boards, plotting boards, and other devices hinging on a system of graphic plotting, may be replaced by the development of schemes in line with the probable necessities of future fire control problems.

For instance, at extreme ranges with a hostile target hull down, it may not infrequently be wholly impossible to get accurate intersections upon the target from two base end stations at all times, and yet with such tracking of the target as may be had from either one station, balloons, possible airplanes, or by a combination of available means, the target must needs be tracked. Now the significant requirement of this tracking is not so much that the actual range shall be correctly determined as that the the true range-travel and deflection-travel relations shall be obtained. Again, even if intersection upon the target is possible from base end stations, at long ranges of 30,000 to 50,000 yards, with base lines of practicable lengths, the intersections at the target would form such acute angles as to introduce considerable and unsystematic errors in graphic plotting. There are numerous Coast Artillery officers who believe that the future system of tracking moving targets will result from a development and adaptation of the principle of nomographs. There are very definite mathematical limitations to the adaptability of nomographs to give a certain series of results from a given series of data, but it is believed wholly possible that the ingenuity of Coast Artillery officers will suggest convenient methods of combining different nomographs to accomplish the determination of range and azimuth of targets for any field of fire possible to any given battery. The JOURNAL expects to present an important article on nomographs in an early number.

Some of the significant changes in methods of preparation of fire and conduct of fire indicated by recent experiments in long range fire control are worthy of the consideration of all Coast Artillery officers. Briefly, the indicated line of progress seems to be something as follows:

(1) A plotting board of the present form, or some other may be used, until some better system of tracking is developed, such as a scheme of nomographs or a mechanical range keeper developed along the lines of the instrument used by the Navy. When a plotting board is used, its only function will be to determine the successive positions of the target from two or more base end stations, relocated for a given directing point. All operations such as determining the set-forward range and azimuth and the predicted azimuth will be entirely removed from the plotting board.

(2) The data for any target determined from two or more stations must be simply relocated for any or all batteries which can be brought to bear upon the target.

(3) For any given battery, the data coming in to the fire control section will consist of the successively relocated positions of the target. With these data as a basis, the range will be taken by one operator to a range prediction device, where the set-forward range for a given predicted time will be determined. From this range prediction device, the set-forward range will be taken to a range correction board, similar, perhaps, in principle to the Pratt Range Board, and this corrected range will be sent to the guns. From the relocated data coming to the fire control section, the deflection element will be taken off and handled in a similar manner on a deflection or azimuth predicting device, to determine the set-forward azimuth at the same predicted time as that for which the range is determined, from which the set-forward deflection or azimuth will be obtained and used on a deflection correction board, from which the corrected deflection will be sent to the guns.

(4) The principle of fire control to be employed will be that data corrected for meteoroligical conditions, and all other

elements effecting the accuracy of the fire, which may be predetermined, will successively be applied in each range sent to the guns up to the time of opening fire, after which the ranges to be determined must be made to conform to the time-travel relations of the target, without introducing into the transmitted data any variations resulting from the variations in the corrections which would result from changes in meteoroligical or ballistic conditions. This suppression of variations in corrections will continue until fire adjustment has been completed. As soon as fire adjustment is completed then the fire control section must be able to re-introduce into subsequent data the variations in corrections which had been suppressed after the original salvo. The idea involved is that when once fire adjustment is undertaken, this adjustment must account for the failure of the summation of all corrections to place the center of impact on the target. Consequently, after adjustment has once started, the ballistic and meteorological corrections should not be changed, otherwise the adjustment will be compelled to take care of an indefinite and indeterminate number of variables. On the other hand, after the adjustment has been effected, the inaccuracy of the ballistic and meteorological corrections will have been accounted for, and in order to keep the center of impact thereafter on the target, it will be necessary not only correctly to maintain the time-travel relation, but also to maintain the indicated ballistic and meteorological corrections, indicated by the changes in the conditions affecting these corrections.

(5) In order to simplify the work of the fire control section to the extent that this elastic facility of throwing out or throwing in, at will, the effects of ballistic and meteorological conditions may be possible, the whole scheme must be so arranged as to employ the very minimum number of men. It is highly probable, judging by recent experiments, that not more than five men will be required in predicting, transmitting, and recording data.

(6) In order to make observation of fire possible at extreme ranges, it will often be necessary to concentrate all guns upon the target which can be brought to bear, firing by salvos. As previously emphasized in the JOURNAL, this necessity will call for a newer acceptance of the meaning of calibration, so that the guns of perhaps two or three fire commands can be used as one battery. Experience may indicate the desirability of firing several batteries either so that the splashes

will occur simultaneously or with the splashes occurring at a pre-determined interval. In order to accomplish this, an electric firing device, involving the principles of a relay delay firing switch, such as has been developed for the Navy, may need to be employed.

(7) The processes of determining range and deflection deviations during observation of fire likewise will have to be independent of graphic plotting, in the sense that we have hitherto understood. Some form of simple plotting board will need to be employed which will readily give the deviations desired at a large scale near the target, and determined at will either from the predicted point or from the position of target at moment of splash. The latest development in the way of a plotting device for this purpose is the Deviation Computer for Moving Targets designed by Lieutenant Colonel John H. Pirie, C.A., and described in his article in this number.

Our duty toward every technical problem and device with which we are concerned, should be that we never will have developed or adopted anything which represents the ultimate crystallization of perfection. What we did before the war represented the latest thought and the best ideas up to that time. We are bound now, in the light of our experience in the war, to swing sharply on a new tack. We cannot believe that the developments of the immediate future, roughly indicated herein, represent anything more than a present and temporary improvement. Before these ideas will have been developed to their uttermost, it may and should occur that something newer and radically better will have been achieved. This is the path of progress, and we should not be discouraged if the fruit of our earnest toil is supplanted almost before it is ripe. But this much is certain that momentous changes are bound to take place, and it is believed that the suggestions herein given may outline a path which, for the immediate present, the Coast Artillery officer in the coast defenses may profitably follow in his investigations.

PROFESSIONAL NOTES

A Method of Computing Differential Corrections for a Trajectory

By Gilbert Ames Bliss,

Professor of Mathematics, University of Chicago

Editor's Note.—This article was originally printed in the June, 1919 issue of the JOURNAL OF THE UNITED STATES ARTILLERY. Through laxness on the part of the JOURNAL, the proof-reading was so carelessly done that the article, as originally published, was inaccurate and unintelligible. In order to do justice to the subject and to the author, the JOURNAL is making what amends it may by reprinting the entire article.

In the following pages a method is explained for the computation of the corrections which must be applied to a trajectory to account for disturbances in the flight of a projectile of the magnitude of those caused, for example, by the wind. Its effectiveness depends upon a device which has been found useful in the computation of range tables by the methods of approximation which have been developed during the war. The details of the mathematics involved in the theory will be presented in a paper to be published with others of a similar sort in a supplement to this Journal. In the exposition here given only those mathematical features are explained which seem indispensable to an understanding of the method.

The fundamental data for the computation of a range table for a specified gun, projectile, and powder charge, are obtained from firings, by observing the muzzle velocity and the ranges corresponding to different angles of elevation of the gun. These observed ranges must first of all be corrected for variations from normal in the conditions under which the actual firings were made, for example, for variations from normal in the temperature and weight of the powder charge, in the weight of the projectile, in the density of the air, and for wind. In the case of long ranges the curvature and rotation of the earth may also be taken into consideration. The accurate computation of the corrections requires a knowledge of the ballistic coefficient to be used in the expression for the retardation law. This value is also unknown at the start, and the corrections are first computed with the help of a ballistic coefficient which previous experience recommends as approximately correct. With the ranges reduced to normalized conditions obtained by making these approximate corrections, a new and sufficiently accurate value of the ballistic coefficient may be obtained, and the range elevation table with its accompanying differential corrections may then be found in its final form by actual computation of one form or another based upon the differential equations of the trajectory.

For flat fire the classical method for finding the differential corrections mentioned in the preceding paragraph is by means of the formulas of the Siacci theory and the Ingalls tables. This method has been exceedingly well organized and is most convenient, but it involves the well-known Siacci approximation which unfortunately can not be justified for higher elevations, though it is a most convenient and helpful device within its range of applicability. So far no scheme applicable for all elevations and analagous to the Siacci-Ingalls theory, by means of which range tables for use in the field can be computed from tabulated data such as appear in the Ingalls tables, has been established in practice, though it is within the range of possibility that such a method can be devised on the basis of the newer theories which have been evolved during the past five years.

In the Siacci-Ingalls theory the reduction in the retardation of the projectile due to the rarification of the air at higher altitudes is accounted for by introducing a so-called altitude factor in the ballistic coefficient. This is not a particularly happy device, and it has been avoided by Major F. R. Moulton, who seems to have been the first to have frankly introduced into the expression for the retardation law itself a factor which suitably reduces the retardation as the altitude increases. The formula for the retardation adopted by Major Moulton is

$$R = \frac{vG(v)\,H(y)}{C},$$

where vG(v) is the retardation, expressed in terms of the velocity v, of a standard projectile moving through air at normal sea level density, where C is the ballistic coefficient which enables this expression for the retardation to be adapted to projectiles of other types, and where H(y) is a factor which is unity when the altitude y is zero and which decreases as observation has shown that the density of the air normally decreases when the altitude y increases. The differential equations of the motion of the projectile then turn out to be:

$$(1)\qquad \begin{aligned} x'' &= -\frac{1}{C}G(v)\,H(y)\,x' = -Fx', \\ y'' &= -\frac{1}{C}G(v)\,H(y)\,y' - g = -Fy' - g, \end{aligned}$$

where x', x'', y', y'' are the derivatives with respect to the time t of the coordinates x, y of the projectile, and F is merely a convenient symbol for the expression $\frac{GH}{C}$.

The crucial functions in the differential equations which have just been set down are the functions G and H. The values of the former have been tabulated from the results of experimental firings and the table has been smoothed with the help of an analytic function which fits it with sufficient accuracy. Several expressions have been given for H(y), among which is the well-known Hamilton law of atmospheric density. For actual computation, however, it turns out that H(y) can be more conveniently expressed in the form of an exponential e^{-ay} where a is a suitably chosen small positive constant. From the standpoint of accuracy it makes little difference which form for the altitude function H is used, provided only that proper corrections are applied to account for the variations from the chosen norm in the density of the air at the time when a particular shot is fired.

The differential equations (1) so established can not be integrated in the usual way by means of known functions, but their solutions can be found by methods of approximation. The trajectory whose form is characterized by them is the one along which the projectile will fly when all conditions are normal. It is not proposed to discuss here the methods by which this normal trajectory is computed. The forms for the computation have been skillfully arranged by Major Moulton and his associates so that the work proceeds with rapidity and accuracy. The purpose of the writer is rather to present methods of computing the differential corrections to the trajectory which, when used in conjunction with Major Moulton's theory, make the labor of computing a range table not excessively greater than that required in the Siacci-Ingalls theory. The new methods have further the great advantage of being applicable with equal degrees of accuracy for all angles of elevation.

Suppose then that a trajectory has been computed as a solution of the equations (1). The actual flight will be in a slightly different path when a wind is blowing or when the density of the air or the initial conditions of velocity or elevation are not normal. The velocity and the direction of the wind at different altitudes can be found as usual by observing a pilot balloon at the time of firing, and the magnitude of the following wind component so determined will hereafter be designated by w(y). There will also be a cross wind effect which can be determined separately, and which for the sake of simplicity will not be considered here. The air density at different altitudes at the time of firing is determined from airplane observations of temperatures and pressures, so that the density function $H+\delta H$ which should be introduced in place of H in the equations (1), to account for any irregularities in the densities of the day at different altitudes, can be regarded as known. The equations of the disturbed trajectory then have the form

$$\begin{aligned} \bar{x}'' &= -(F+\delta F)\,[\bar{x}'-w(\bar{y})], \\ \bar{y}'' &= -(F+\delta F)\,\bar{y}'-g, \end{aligned} \tag{2}$$

where $\bar{x}=x+\xi$, $\bar{y}=y+\eta$ are the coordinates of the projectile on the new trajectory, and δF is the correction to be added to F to account for both the wind and the altered density. The values of ξ and η are clearly the corrections which must be added to the coordinates x and y of the projectile at a point on the undisturbed trajectory in order to obtain the position $\bar{x},\bar{y}$, of the projectile on the disturbed trajectory at the same time t. The details of the mathematical justification for these equations, as for a number of those which follow, are omitted. For the present it is sufficient merely to note them down, so that the meaning of the differential equations about to be deduced for ξ and η may be clear.

When the equations (1) are subtracted from equations (2), two new equations for ξ and η are found. If terms of the second order in the small quantities $\frac{(\xi'-w)}{v}$, $\frac{\eta'}{v}$ are neglected these new equations take the form:

$$(3)\quad \begin{aligned} \xi'' &= x'F\left(a\eta - \frac{\delta H}{H}\right) - F\left(1 + x'^2\frac{G'}{vG}\right)(\xi' - w) - x'y'F\frac{G'}{vG}\eta', \\ \eta'' &= y'F\left(a\eta - \frac{\delta H}{H}\right) - x'y'F\frac{G'}{vG}(\xi' - w) - F\left(1 + y'^2\frac{G'}{vG}\right)\eta' \end{aligned}$$

where a is the constant in the function $H = e^{-ay}$. Ordinarily these equations would have to be integrated repeatedly to get the values of ξ and η for the different types of corrections desired. This is rather a laborious process, however, when methods of approximation have to be used, and it is the purpose of this paper to show how the desired data may be obtained by integrating a single time, instead of many times, a second system of differential equations called the system adjoint to the system (3).

Let ω be the positive angle of fall at the end of the undisturbed trajectory for which the time of flight will be represented by T. Then at the time T the projectile on the disturbed trajectory will have coordinates $(x+\xi, \eta)$, and the difference ΔX of the two ranges has the value

$$\Delta X = [\xi + \eta \cot \omega]^{t=T}$$

as is readily seen from the figure. The quantity ΔX is the one whose value is desired.

The system of equations

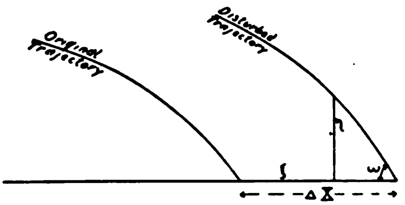

Fig. 1

$$(4)\quad \begin{aligned} \mu' &= -aF(x'\nu + y'\rho), \\ \nu' &= -1 + F\left(1 + x'^2\frac{G}{vG}\right)\nu + x'y'F\frac{G'}{vG}\rho, \\ \rho' &= -\mu + x'y'F\frac{G'}{vG}\nu + F\left(1 + y'^2\frac{G'}{vG}\right)\rho \end{aligned}$$

where μ, ν, ρ are three new auxiliary variables, is called the system adjoint to the equations (3). These equations may be integrated for μ, ν, ρ with initial values $\mu - \cot \omega = \nu = \rho = 0$. at the time T at the end of the trajectory. When the equations (3) are multiplied, respectively, by ν and ρ and added, it is found after some manipulations with the help of equations (4), which will not be explained in detail here, that

$$\frac{d}{dt}(\xi + \mu\eta + \nu\xi' + \rho\eta') = (\nu' + 1)w + \frac{\mu'}{a}\frac{\delta H}{H}$$

The integration of this equation from 0 to T gives

$$[\xi+\eta\cot\omega]^{t=T}-[\nu\xi'+\rho\eta']^{t=0}$$
$$=\int_0^T(\nu'+1)w\,dt+\frac{1}{a}\int_0^T\mu'\frac{\delta H}{H}dt,$$

since $\mu-\cot\omega=\nu=\rho=0$ at $t=T$, and since the two trajectories have the same starting point so that $\xi=\eta=0$ at $t=0$. Hence the value of ΔX is given by the formula

$$(5)\qquad \Delta X=[\nu\xi'+\rho\eta']^{t=0}+\int_0^T(\nu'+1)\,w\,dt+\frac{1}{a}\int_0^T\mu'\,\frac{\delta H}{H}dt.$$

The formula (5) just derived is the basis of the computations of the differential corrections. Everything in it is completely determined when the solutions μ, ν, ρ of the equations (4) are known. If the corrections for altered initial conditions, wind, and density are considered independently of each other, it gives the three formulas

$$\begin{aligned}&\Delta X=[\nu\xi'+\rho\eta']^{t=0},\\ (6)\qquad&\Delta X=10\ [t_2-t_1+\nu(t_2)-\nu(t_1)\ ],\\ &\Delta X=\frac{.01}{a}[\mu(t_2)-\mu(t_1)\ ],\end{aligned}$$

respectively, for the range corrections due to changed initial conditions, to a 10m/s wind blowing from a time t_1 to a time t_2, and to a one per cent variation from normal in the density of the air ($\delta H/H=.01$) on the part of the trajectory traversed between the times t_1 and t_2.

The results described above may be summarized as follows. Suppose that a trajectory for a projectile traveling under normal conditions has been found from equations (1) by a method of approximate integration. Then in order to find the corrections to the range of the projectile which must be made to account for wind or for abnormal initial conditions and air-density, it is necessary to integrate the equations (4) once, by approximate methods, for the three auxiliary functions μ, ν, ρ, with initial conditions $\mu-\cot\omega=\nu=\rho=0$ at the time $t=T$ at the end of the trajectory. The required corrections may then be calculated from the formulas (6) by the elementary operations of arithmetic. This process replaces the repeated integrations for the differential corrections which must be made if the equations (3) are used directly. The mathematical argument which justifies the method here explained is perhaps somewhat complicated, but it needs to be made but once, and it leads to simple formulas which save much labor in the actual computations.

The corrections for cross wind and the rotation of the earth, and a method of solving the more complicated problem of the corrections for anti-aircraft firings, may be deduced by similar considerations. These are, however, beyond the scope of the present paper, and will be described in the articles mentioned in the first paragraph above.

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BOOK REVIEWS

Dyke's Automobile and Gasoline Engine Encyclopedia. (10th Ed.) A. L. Dyke. St. Louis. 7"x10". 960 pp. 3362 il. Price, $5.00.

This remarkable book has again been revised and greatly improved. It could appropriately be termed a "Repairmans Guide." In addition to its mass of information on Automobiles, covering every detail from the construction and repair of the axle to the repair of radiator and top, many new subjects have been added. For instance, how to make electric tests of the starting motor, generator, battery, coils, magnetos, etc. In fact, the subjects are dealt with in such a simplified manner that one can almost understand by a mere glance at the numerous illustrations.

The storage battery subject, is profusely illustrated, and anyone who can read plain English can soon learn how to diagnose trouble, disassemble, repair, assemble and recharge batteries. A feature of this instruction is a simplified explanation of the "Cadmium Test" of a storage battery. One naturally thinks of a very technical and complicated subject, but after reading this subject and a glance at the numerous illustrations the "tech" part becomes perfectly clear.

The book covers practically every phase of the Automobile industry and deals with Automobiles, Trucks, Tractors, Motorcycles, Airplanes, Airplane Engines, including the Liberty Engine, fully illustrated. There are supplements with 332 illustrations on the Ford and Packard car, part printed in colors. Every detail of the Ford is explained. For instance, how to rebuild a Ford and make it do 60 miles per hour; how to make every known repair from the axle to the engine. The Ford new electric system is fully illustrated, in fact the illustrations go so far as to show the internal wiring of the "cut-out" and its principle of operation. There are also five colored Inserts, a Dictionary, and a deal more of valuable information, too numerous to mention. It is a book which every automobile owner should have.

The Division General Staff. G-1. By Andrew L. Pendleton, Jr., Lieut. Col., Coast Artillery Corps. New York. Edwin N. Appleton, Inc. 7-¾"x10-3/8". 96 pp. 23 large maps and diagrams in back cover pocket. Price, $3.50.

Before our participation in the Great War, the general conception of Staff Work was elementary on the part of the large majority of American officers. Those who shared to any extent in the operations in France now realize that tactical success depends as much upon skilled staff administration as upon the courage and training of the troops. So the scope of required knowledge on the part of the Regular officer will be enlarged to include staff training.

This particular book is a valuable basic guide for the administrative phases of staff work. It covers the ground of G-1 duties, and so far is the only comprehensive manual in this particular field. The author does not claim for this method in toto that it is the best, but that it represents actual experience, and that it is good because it has worked. It is almost hackneyed to say "This is a book which should be in every officer's professional collection," but in this case the statement is eminently true.

* * *

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By Capt. R. R. Belknap, U. S. N.

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Practical Interior Ballistics (concluded)

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Journal of the United States Artillery

Published under supervision of the Coast Artillery Training Center Staff, by direction of the Chief of Coast Artillery.

12 numbers per year; volumes begin January and July. Issued on 15th day of each month.

Entered at the Post Office at Fortress Monroe, Va., as second class matter.

Subscription price, per annum:

Domestic	$3.00
Canada	3.25
Countries in the postal union	3.50
Single numbers	0.30

All subscriptions payable in advance.

Subscriptions may be entered to begin with any desired issue of the Journal. It is suggested that those who have not the numbers beginning with January, 1919, will find it desirable to begin with that issue, as all the numbers from there on are filled with especially live, important matter.

Make checks, drafts, and postal orders payable to Journal U. S. Artillery.

Remittances, articles intended for publication, and communications relating to the management should be addressed Journal U. S. Artillery, Fort Monroe, Virginia.

It is earnestly requested that prompt information be given of changes of address, or failure to receive the JOURNAL. Both old and new addresses should be given.

Lieut. Col. F. S. Clark, C. A.
Manager and Editor

Major Wm. C. Foote, C. A.
Assistant Editor

London Agents:
B. F. Stevens and Brown, 4 Trafalgar Square

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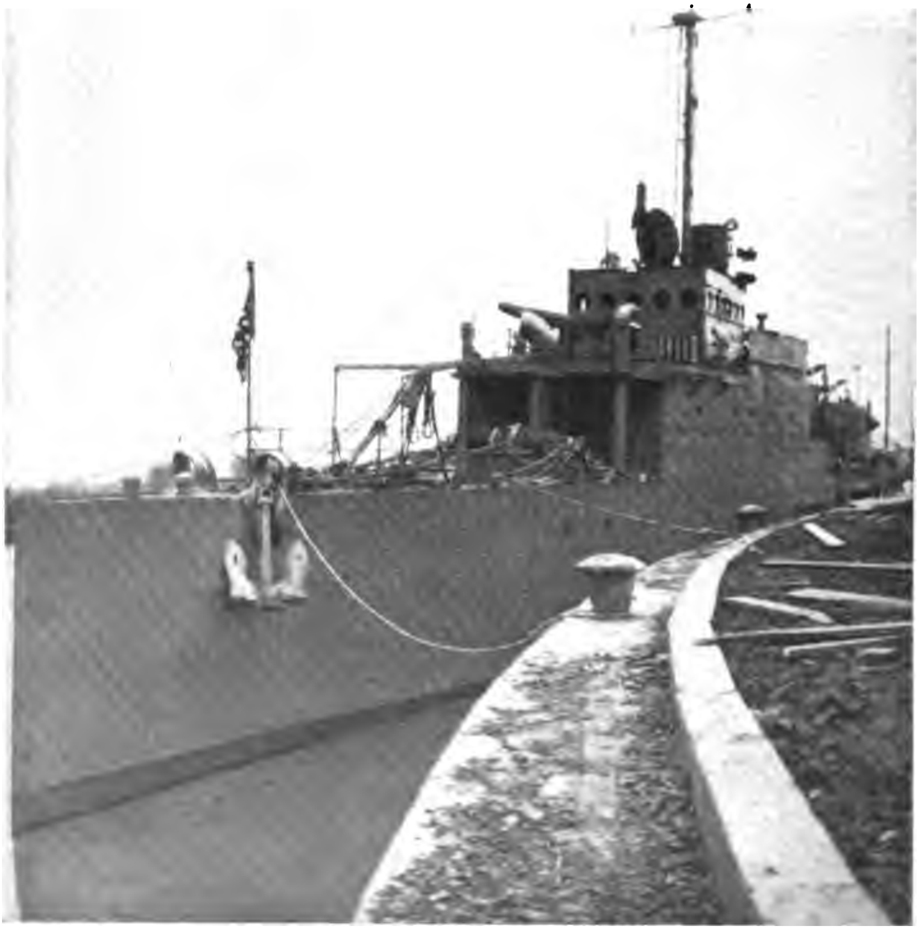

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JOURNAL

OF THE

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VOL. 51, No. 5. NOVEMBER, 1919 WHOLE No. 159

Submarine Mines in War

By Captain Reginald R. Belknap, U. S. N.

Commander of the U. S. Mine Laying Squadron in the North Sea Mine Barrage Operation, 1918

The history of nearly every war in which United States Forces have been engaged on the sea shows the employment of submarine mines, generally with success. The same is true of other wars, and in that between Russia and Japan mines were the direct cause of the sinking of seventeen vessels of war, among them being three first class battleships—not a small portion of the whole number then possessed by the nations in question. Eight other men-of-war were seriously damaged, and a considerable number of other vessels, belligerent and neutral, became victims, in more or less degree, of the same weapon.

Very soon after hostilities began, the mere presence of mines, real or suspected, exerted a powerful influence on naval operations, on several occasions causing such hesitation, delay, or inactivity as to give strong ground for the belief that, but for mines, the outcome of the Russo-Japanese War would have been radically different. In the words of a French writer "the mine showed itself to be a terrible engine of destruction."

Such a demonstration as that war gave of the important military value of the submarine mine did not lead to the thorough study of its possibilities that would have been justified, either as to mechanical development or belligerent employment. Conservation towards a weapon that is new—as the mine was in some of its uses—is hardly overcome without what may be termed popular support, and submarine mines could never look for popularity. Examples of their military effectiveness had been accompanied by occasional damage to innocent shipping, which so outraged an influential body of opinion as almost to condemn the mine altogether. Some of the new uses of mines promised to be more advantageous to weak than to strong powers. Minelaying and other mine operations, though indeed hazardous enough, seemed crude and otherwise unattractive to the general naval mind. And an apparent kinship too close to assassination held the weapon in a questionable repute, which brought for even its legitimate successes a cold reception. Usefulness had been too well proved for mines to be neglected, yet a comparative indifference, coupled with general aversion, seriously increased the difficulties of those who foresaw an extensive future for the mine and sought to prepare for it. Even in Germany, where mine affairs were better developed than elsewhere, a captain in charge of them in their Admiralty, a few years before the war, remarked "the mine has no friends." The net result seemed to be a desire more to suppress the mine than to further its reasonable development.

In this country, in comparison with the gun, the torpedo, and aircraft, the mine received scant attention before 1914, certainly less than was given it by any other great power. With the outbreak of the war in Europe came an awakening. Among the first casualties on the sea were some that were due to submarine mines, and thenceforward their employment became more and more extensive, culminating in the great North Sea mine barrier, stretching from the Orkneys 230 miles across to Norway.

Some idea of the growth of the employment of mines may be gathered from the numbers of them laid and from their toll of sinkings. An official bulletin of November, 1918, stated that 128,000 mines had been laid by the British during the war, 56,500 by the United States, and about 20,000 by the enemy, a total of about 205,000 mines, valued at between 100 and 150 millions of dollars, not counting any costs for the minelaying.

An official return issued in March, 1919, of allied war vessels lost during the war, combined with an earlier return which included also a partial list of enemy losses, gives the following numbers sunk by mines:

	Allied	Enemy	Total
Battleships	6	--	6
Cruisers	4	2	6
Light Cruisers	3	2	5
Monitors	1	2	3
Torpedo Boats	10	10	20
Sloops	5	--	5
Destroyers	31	15	46
Submarines	4	10	14
Armed Merchant Cruisers	2	--	2
Miscellaneous	7	23	30
	73	64	137

This list does not include any merchant vessels nor the full loss of enemy submarines, but as it stands the total is strikingly large, even to those who expected much. Of 418 war vessels lost by the allies from all causes, the number sunk by mines represents over one-sixth, not to mention more than a few others that were damaged, though not destroyed, by the same cause.

Four distinct uses of the submarine mine may be recognized, with corresponding character differences among the mines employed.

Mines may be classified primarily as either stationary or anchored mines, or else as drifting or floating mines.

The first class, anchored mines, differ in type according to whether their firing is under control or not. If under control, they are termed *controlled* or *observation* mines; if not under control, they are called *contact* mines. Controlled mines may be fired from the control station by *judgment*, when a vessel is known to be over a mine, either by plotting her track or by an electric signal from the mine itself; or the mines may be set for *automatic* firing, with the control switch closed, in which case a mine will then explode upon contact by a vessel, and that minefield is for the time being a field of contact mines. Numerous other differences exist, affecting the firing device, depth setting, operation of the anchors, safety attachments, and other features. These need not be gone into here, since they do not bear upon the principles of classification but only upon the efficiency of operation.

The use of controlled mines is the one most familiar on our coast. Such use is limited to the defense of the entrances and approaches to harbors and to passages in situations where suitable control points may be established within good visibility distance. In most countries, if not all, minefields of this kind come within the same province as the coast and harbor fortifications. With us, they come under the Coast Artillery, or, at outlying Naval bases and certain other points, they come under the advanced base force or local garrison of Marines. An extension of the same use would employ controlled mines to guard coastal areas lying beyond the reach of fixed fortifications, and such minefields, in the United States, would lie in the province of the respective Naval District forces.

Controlled mines are comparatively large and bulky and their handling is encumbered by the cables for the control connections. To plant a minefield of this kind is a slow operation, requiring good weather and comparatively smooth sea. Hence controlled mines are not suitable for use in exposed positions on the high sea or in any mining operations involving the laying of mines in considerable numbers, done at command and in a short time. Their chief value lies in their suitability for guarding channels through which innocent or friendly traffic is to continue. The recent war has broadened this use, showing that the control station need not be on shore nor even within sight of land, thus allowing controlled fields to be planted farther off shore than before. But wherever such a minefield be placed, unless adequately protected by batteries and patrol vessels against enemy raid, the field may be quickly swept up or its connections severed by dragging. Controlled mines are therefore inherently defensive in their use and are to be regarded as supplementary to other fixed means of the local defense of comparatively strong and important positions.

Anchored contact mines are smaller than controlled mines and as a whole more compact. The mine proper, with its anchor and reel of mooring cable, when assembled ready for mooring in place, form a unit that can be easily transported, quickly and safely embarked by ordinary cargo handling equipment, and rapidly laid, successive mines being launched at intervals of only a few seconds, from vessels steaming at as high speed as 25 knots, even in moderately bad weather. Their development during this war reached a stage where mines were laid in considerable numbers in water as deep as 900 feet, some of them being submerged as deep as 240 feet beneath the surface. Still greater depths and greater submergence are easily within the possibilities of mechanical development.

This type of mine may be used in any location on soundings except where friendly or innocent vessels are to be allowed to pass. Once down, these mines cannot be rendered harmless at will, but remain constantly dangerous to both sides alike. They are suitable for the defense of a belligerent's own waters or advanced bases, or they may be employed offensively, to deny or delay the enemy's occupation of desired places or to obstruct channels and sea areas against him.

Used defensively, anchored contact minefields may be so placed as to alter completely the navigable character of an extensive sea area. Foul ground may be placed where desired, so that hostile vessels may be held off beyond range from any harbor or base and the approach to it limited to directions and channels that may be strongly commanded. Bombardment or even observation by raiders would be prevented, unless they were prepared to sweep a way through the mine obstructions, accepting the attendant encumberment, delay, and exposure to counter attack.

The use of contact minefields defensively has been common since our Civil War, though with but small numbers of mines until recently. In this latest war, not only belligerents but also neighboring neutrals have laid extensive contact minefields, the former to add to their coastal and harbor entrance protection, the latter to secure their territorial waters against violation.

When such minefields are duly notified and safe guidance through is available to those entitled to pass, the effect is nearly the same as if the local hydrography had been changed by nature, and, just as with natural dangers, there is always the unavoidable disadvantage, in resorting to defense by contact minefields, that they are dangerous to hostile and friendly alike. The main difference is that getting out of the safe channel may be more dangerous than mere grounding on a bank or rock.

The most extensive and conspicuous use of anchored contact mines during the late war was distinctly offensive. Immediately on the outbreak of hostilities, minelayers were despatched from Germany to plant minefields on the coast of Britain, and one such vessel was destroyed off the mouth of the Thames early in August 1914. From then on, minelaying operations in or near the enemy's waters continued throughout the war. Minefields in countless number and varying in size from groups of six mines to upwards of a hundred were laid, mostly by the Central Powers, off harbor entrances, near headlands, in coastwise channels and routes, and in straits and inter-island passages. In return, the British were continually laying mines in the Heligoland Bight, making foul ground of an immense area lying north and west from Heligoland, besides other operations on the Flanders coast.

Considerable damage was done by these fields, to merchant vessels as well as war vessels. And the damage was not confined to losses of ships, for the frequent delays to shipping while channels were being cleared from time to time, and the extra length of voyage, due to following specified swept routes instead of the direct routes possible in peace, piled up the shipping costs and decreased the amount of transportation which the tonnage available could effect in a given time.

This minelaying campaign, moreover, necessitated the constant employment of mine sweeping craft, numbering by the hundreds. The large fleets of steam trawlers employed in fishing about the British Isles and on the French coast made it possible to establish, soon after the war opened, an admirably comprehensive organization for keeping channels clear for traffic wherever necessary or desirable. Although the crews of mine sweepers were small, their aggregate number made a considerable draft on the seafaring personnel. Thus a comparatively small number of mines, laid now and then, caused a large effort to guard against them to be kept up unceasingly, besides the direct loss in the use of tonnage, through sinking or delay.

The shipping of the Central Powers being swept off the sea made the merchant shipping losses from mines fall mainly upon the belligerent which had command of the sea. That command was not complete enough to stop the enemy's mine laying by submarines and by an occasional raider escaping through the blockade. The latter carried the enemy's mines to the British, French, and Mediterranean shores and even to the waters of the United States, India, and Australasia. This far-flung part of the minelaying campaign was surprising and spectacular, but it could not be maintained, nor even begin, in sufficient strength to have more than temporary and local effect. Great importance attaches to it, however, as a warning of what may be done, and what to prepare against in the future.

Employment tactically during sea engagements is another use of mines of which as yet there is little authentic information available as to methods and results. For this purpose, the floating or drifting mine has been the type deemed most suitable. Such mines, having no anchor, are comparatively light and compact, easily carried and launched. Their use is independent of the depth of water. Hitherto, the use of anchored mines for such a purpose—instances of which have been suspected or questionably reported—has been thought to be limited to waters not over 180 feet deep. But during this war, it has been shown that anchored mines may be quickly and easily laid, on short notice and in considerable numbers, from destroyers, scouts, or larger vessels, in depths of water as great as 900 feet or more—in other words, anywhere on soundings. Thus, it is well within practicable possibilities that anchored mines as well as drifting ones, may play an important tactical part in future engagements of sea forces. For us this holds considerable interest, in view of the wide area bordering our coasts where depths do not exceed 600 feet.

THE NORTH SEA MINE BARRAGE

Standing out from all other mining operations was the laying of the Northern Barrage, that great minefield barrier across the North Sea, from the Orkney Islands to Norway. This measure aimed to supplement the convoy system and the patrol against submarines, by stopping the submarines near their home bases, before they could scatter over the trade routes.

The minefields laid by the British off the German coast were no obstruction to submarines using the Skagerrack, a passage that could not be closed without violating neutrality, nor—of still more weight under the circumstances—without the constant presence of a stronger supporting force than the Allies were prepared to maintain there, 450 miles from the nearest base in Great Britain. Such a force would be exposed on the flank and rear, as well as in front, and the nearness of the German bases made a sudden attack in force, at a time chosen by the attacker, not merely easy but practically certain.

The line first decided upon for the barrier ran from Aberdeen, Scotland, to Ekersund, Norway, about 40 miles below Stavanger. The distance was 240 miles. The depths of water over three-fourths of this line did not exceed 300 feet, which was not deeper than mines had already been laid in

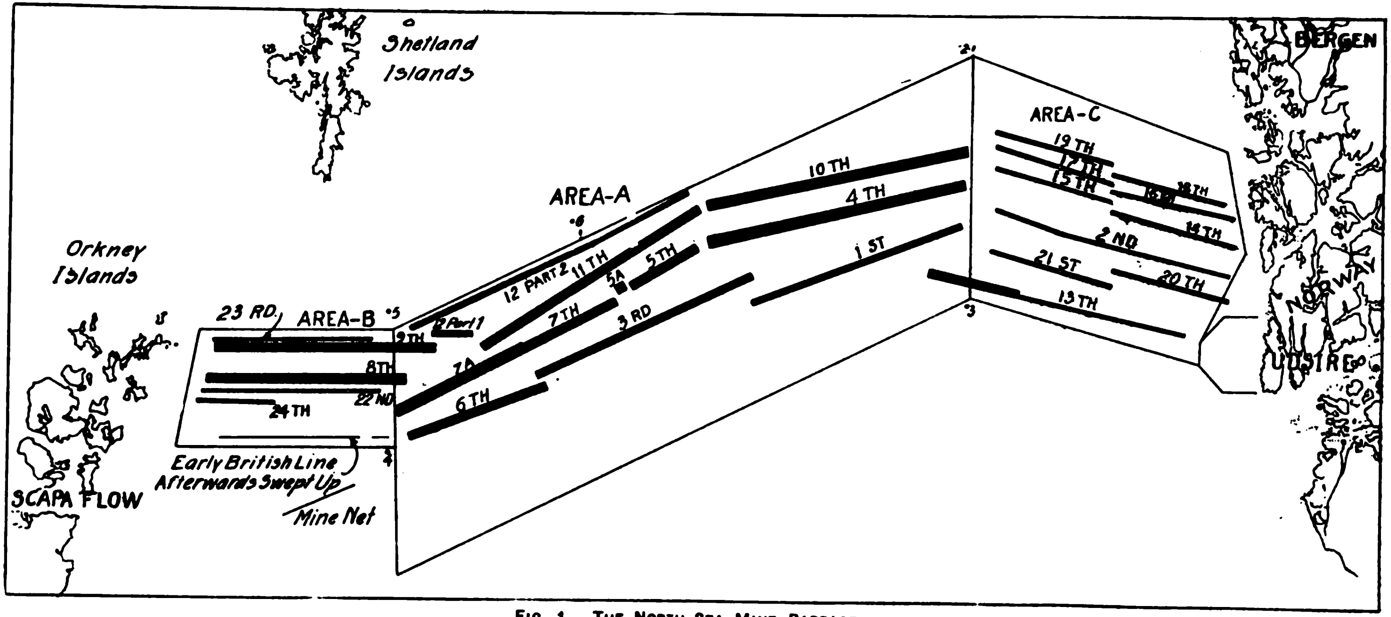

FIG. 1. THE NORTH SEA MINE BARRAGE

successfully, but near the Norway coast the water deepens to 900 feet or more, which introduced an untried feature. Given sufficient buoyancy in the mine proper, however, and enough length of mooring cable, no real difficulty was to be apprehended that would make planting less certain at greater depths than at those already tried.

The possibility of such a barrier being effective, the enormous amount of material involved, the long time required for laying it, even with experienced personnel, the probability of enemy interference, and the inherent danger to the minelayers in successively approaching their own fields, previously laid in the open sea, near enough to make the barrier sufficiently continuous throughout its length—all these features of the problem were discussed during the four days' consideration of the project by the Naval General Board before giving its approval.

The plan included an advance notification to neutrals of the location of the central section of the barrier. Such a notification would become common knowledge, and the enemy would naturally infer that the notified section was only part of a barrier that would extend, sooner or later, completely across the North Sea.

The barrier was to be effective against submerged submarines, as well as against surface vessels. In fact, the wing sections were at first planned to contain only deep mines, the passage of surface vessels over them to be prevented by patrol, but this was soon changed to make obstruction against both surface and submerged passage alike throughout the length of the barrier.

The magnitude of the undertaking may be gauged by comparing the number of mines needed—40,000 first estimated for the middle section alone—with the few hundreds formerly considered as constituting a large minefield. Of the mines that we were to use, the very basis of the whole project, a single unit did not exist. Some of the minor but still essential details had not even been devised. So the decision to proceed with the operation had to be taken on the assumption that the mine as a whole, when assembled, would be as successful as the trials of several parts had been. This was a bold course, but time pressed and the need was great.

Of minelaying vessels at the time of discussion, October, 1917, the British had sufficient to lay 10,000 mines a month, their vessel of largest capacity carrying 500 mines. The

United States Navy possessed two minelayers fit for the operation, the cruisers *San Francisco* and *Baltimore*, 28 years old but still in excellent condition. Their capacity under prospective conditions would be 1400 mines monthly. Not all the British minelayers could be employed on the Northern Barrage, and the section assigned exclusively to the American force was to contain 35,000 to 40,000 mines. Our manufacturing output was to be 1000 mines a day. Hence a considerable addition to our minelaying squadron was necessary, in order to complete the barrage as soon as possible, and it was decided to expand to capacity for 5500 mines at one laying, or about 22,000 mines monthly under the average conditions to be expected. Then, if there were no delays, the whole barrage might be completed in three months.

One thousand mines a day became the guage for all preparations, which included the establishment of a large plant at Norfolk, Virginia, for charging the mines with the explosive, and the exclusive assignment and equipping of a large steamship pier at Norfolk, for stowing the mine parts awaiting shipment and for loading the mine carriers. The numerous mine parts, manufactured by some 500 contractors, scattered over the eastern and middle states, flowed to Norfolk, whence 24 specially allotted small cargo steamers, two or three sailing in convoy every eight days, transported them to the west coast of Scotland. There they were sent by rail, or by barge through the Caledonian Canal, to Invergordon or Inverness, on Moray Firth, just above Aberdeen. At each of these places a mine assembling base had been prepared, manned by a force of twenty American Naval officers and one thousand seamen, to do all the work in preparing the mines for issue to the minelayers, ready for laying. The whole shore establishment was under command of Captain O. G. Murfin, U. S. N., and, together with the Mine Laying Squadron and the repair ship *Black Hawk*, formed the Mine Force, a separate part of Admiral Sims whole command. It was under the immediate command of Rear Admiral Joseph Strauss, U. S. N., Commander of the Mine Force, U. S. ATLANTIC FLEET, with headquarters at Inverness. The personnel of the Mine Force, afloat and ashore, numbered about 250 officers and 7000 men.

Up to this point, all arrangements were industrial in nature, pertaining to the supply of the weapon to be used. Towards meeting the requirements for employing it to good advantage, we fortunately had in our Atlantic Fleet a minelaying organization which, though small in capacity, was well trained and not without experience of direct application to the task projected. It had been developing under my command during nearly three years, with such effect that the feeling prevailing in its midst towards the new task, as far as it had been disclosed, was one of entire confidence.

How the additional minelaying capacity was provided and what the principle characteristics of the minelayers were, the table shows. The conversion of the new vessels began in November, 1917, and along with it went the organizing and training of their crews. Many were the vexatious delays, in spite of efforts to anticipate every probable cause of them, but on May 11, 1918, seven of the ten vessels were ready, and their crews sufficiently shaken down, to warrant sailing for abroad. After an eventful passage over, the Mine Squadron arrived at its bases in Scotland ready to begin operations, May 26, 1918, and twelve days later, at midnight, June 7, it departed on the first minelaying "excursion."

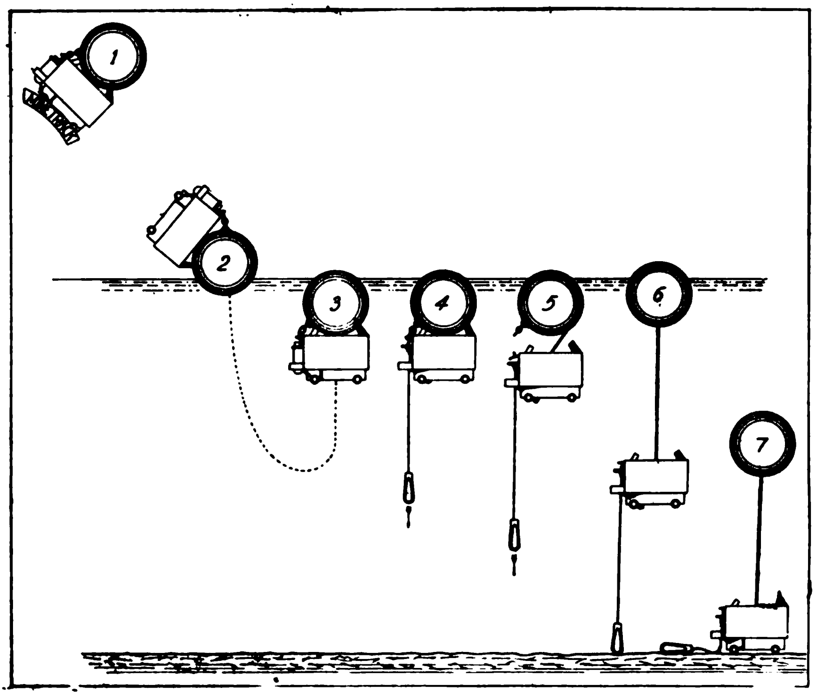

FIG. 2. METHOD OF LAYING MINES

MINE SQUADRON ONE, U. S. ATLANTIC FLEET

Captain R. R. Belknap, U. S. N., Commanding

	Disp.	Speed	Mines	Officers	Men
**San Francisco*, Captain H. V. Butler, U. S. N. (Flagship)	4583	18	170	22	370
**Baltimore*, Captain A. W. Marshall, U. S. N.	5482	18	180	21	339
†*Roanoke*, Captain C. D. Stearns, U. S. N. (ex *El Dia*)	7000	15	normal 830 max. 904	21	400
†*Canandaigua*, Captain W. H. Reynolds, U. S. N. (ex *El Siglo*)					
†*Canonicus*, Captain T. L. Hohnson, U. S. N. (ex *El Cid*)					
†*Housatonic*, Captain J. W. Greenslade, U. S. N. (ex *El Rio*)					
‡*Quinnebaug*, Commander D. P. Mannix, U. S. N. (ex *Jefferson*)	5150	16	614	18	392
‡*Saranac*, Captain Sinclair Gannon, U. S. N. (ex *Hamilton*)					
§*Shawmut*, Captain W. T. Cluverios, U. S. N. (ex *Massachusetts*)	3800	20	normal 320 max. 352	20	346
§*Aroostook*, Capt. J. Harvey Tomb, U. S. N. (ex *Bunker Hill*)					

*Built in 1888-9 as protected cruisers. Commissioned as minelayers in 1911 and 1915. Battery four 5″ guns, two 3″ sky guns. Twin screws.

†Built at Newport News, Virginia, in 1899-1901, as freight steamers for the Morgan Line (Southern Pacific Co.) between Galveston and New York. One 5″ gun, two 3″ sky guns, single screw. These four ships carried mines on three decks, with four hydraulic and two electric, Otis Co., standard platform elevators each, to raise the mines on the lower decks to the launching deck.

‡Built in 1888-9 as coastwise passenger and freight steamser for Old Dominion Steamship Co., New York and Norfolk, Va. One 5″ gun, two 3″ sky guns. Single screw. These two ships carried mines on two decks, with four hydraulic elevators each.

§Built in 1907 as bay and river steamers, passenger and freight for the Eastern Steamship Co., Boston to New York daily service. The steel hulls were strengthened and the superstructures rebuilt at Boston Navy Yard, for conversion into mine planters. One 5″ gun, t8o 3″ sky guns. All mines carried on one deck. Oil fuel. Twin screws.

Being lightly armed and of only moderate speed, besides carrying a cargo too dangerous to be subjected to hostile gun-fire or a submarine's torpedoes, our squadron needed a destroyer escort with it and also a heavier supporting force not far away, strong enough to deal with any enemy interference. These mining excursions were usually so arranged that the American and the British minelaying squadrons might go out at the same time, when, though not acting together, they could be under the protection of the same supporting force. Accordingly, about forty-eight hours in advance, Admiral Beatty, Commander-in-Chief of the Grand Fleet, would issue an operation order, specifying all the forces that would take part—1st minelaying squadron, 2nd ditto, escorting destroyers for each, the support, consisting of a battleship or battle cruiser squadron, sometimes both, and occasionally also a light cruiser squadron, with destroyer screens for all. The order gave instructions, times, and data necessary for the operation of all, and it always set a time limit for the completion of the minelaying.

Our escort of destroyers would arrive by twenty-four hours before starting time, which was usually at night. The two parts of our squadron, separated while loading at the two bases, would join up, together with our escort, off Cromarty, then proceed up the coast, through swept and searched channels to Pentland Skerries, off the northernmost point of Scotland. There the support would come out from Scapa Flow and take its intercepting station on the side from which enemy interference was to be expected. We would then proceed towards the landmark, or towards one of the large buoys placed for such use in connection with the barrage, which lay nearest to the point where we were to begin minelaying. The navigating was done with all possible accuracy, in order to locate the minefields reliably, because we would have to come near them soon afterwards ourselves, to prolong or parallel them, and also because later they would have to be swept up. On the first two occasions, Udsire lighthouse, on the coast of Norway, was used as our point of final departure, from which, the first time, we ran 50 miles off shore before beginning to mine.

For measurement of the distance actually made good over the ground, the "taut wire" measuring apparatus was used, consisting of fine piano wire, which was furnished in spools of 140-mile lengths, wire and spool together weighing one ton. An eighty-pound weight anchored the end of the wire to the bottom and, as it reeled out, a registering wheel showed the distance ran over the ground. A cut with a hatchet stopped it. On reaching a turning point, two more weights would be clamped on, so that the pull would always be directly astern. On one foggy day the flagship *San Francisco*, during the return to base, ran taut wire for 122 miles without a break.

Since the first planning, several considerations had operated to move the location of the barrier northward, to the line from the Orkney Islands to the Norway coast between Bergen and Stavanger. The laying of the barrage began with the British Squadron consisting of four ships, laying 1294 mines in two parallel lines 26 miles long at 65 feet submergence, in the section nearest the Norway coast, called Area "C," while on the same day, the American Squadron, only six ships taking part, laid 3385 mines, in three parallel lines, 46 miles long, at three levels—near the surface, 160 feet under it, and 240 feet under it—starting at the southeast corner of the middle section, called Area "A," and running WSW. The two squadrons, although often out at the same time usually worked in different areas. They seldom met, but on two occasions, in September, 1918, they did combine to mine across the western section, near the Orkneys, called Area "B," the mining of which made the barrier continuous over its whole intended length.

Our second excursion, June 30, laid mines near the surface, across the 900 feet deep water in Area "C," beginning just outside three miles off the Norway coast. Within a week afterward there were results. Our first two fields crossed the submarines' usual route in to, and out of, the North Sea. Two were damaged by mines there, but were helped by another submarine to get back to Germany before the intercepting force could catch them.

All ten American minelayers were present on July 15, 1918, when the squadron laid 5400 mines in five parallel lines 54 miles long—three at upper level, one middle, one lower—this field joining the end of the first. The maximum number of mines ever laid at one time was 5520; and 1300 more were laid by the British Squadron at the same time, September 20, 1918, as part of the same minefield, making it the largest ever laid; a total of 6820, laid in 3 hours and 50 minutes. They were laid in seven parallel lines, 46 miles long, 500 yards apart, 300 feet between American mines in the same line. The British mines, of a different type, were laid closer together.

There were, in all, thirteen regular and two special excursions by the American Squadron, and eleven by the British. Together they laid 70,117 mines, of which 56,571 were American. The minefield occupied an area 230 miles long, averaging 25 miles wide, forming an obstruction to any vessel drawing ten feet or more, whether on the surface or submerged. The obstruction extended as deep as 240 feet over all but the eastern section where it went only as far down as 125 feet. Rows of mines were 500 yards apart which was as near together as it was safe for minelayers to steam in line abreast formation. The spacing between mines in the same row was 300 feet—as near as they could be without suffering structural damage in case a neighboring mine exploded, as from 6 to 10 per cent defective mines did.

A vessel of 30 feet beam thus had four chances in five of passing through a single barrier line of mines unharmed, but as there were from six to ten lines in parallel, the chances of slipping through the whole barrier unharmed varied from only one in four where the barrage was thinnest to one in nine where it was thickest.

Compared to previous minelaying operations, the manner of laying the Northern Barrage suggests the difference between line drawing and painting with a broad brush, or between single and gang plowing. Taking departure from the nearest navigation mark, the American Mine Laying Squadron would proceed—with all possible steadiness and directness, for the sake of accuracy in locating the field—steaming at 12 knots in compact formation, towards the small buoys marking the end of the minefield that was to be prolonged. Upon sighting them, the course of the formation would be so changed that, upon arriving abreast the mining start-point, a simultaneous 90-degree turn by ships would bring the squadron into single line abreast, with 500 yards between ships, all heading in the direction the field was to be laid. After a minute or so on the new course, to make sure all were right, upon signal from the *San Francisco*, five, (usually) ships would begin to drop mines. By this method, a former minefield would be prolonged with a gap of only a mile or so.

As soon as a ship's mines had been laid, her successor would at once begin. To enable this to be done without leaving gaps in the line the minelayers that were to continue the mine-laying after those that began it had laid all of theirs, would be steaming in the same line abreast throughout. Not all ten would be in the same line at the same time however, as that would have widened the minefield unnecessarily. There would be usually eight ships in line to begin with. The other two, 500 yards in advance, would ease back to the minelaying line as soon as ships astern of them had emptied themselves and vacated their places by speeding ahead. By this arrangement it was possible to limit the width of any field to 3500 yards. The more compact, of course, the better was the field.

Looking at the squadron from ahead or from the flank, the only indication as to which of the ships were laying mines at any given time was a red flag at the masthead of each that was laying. From the signal to begin, the minelaying ran with precision on a time schedule, one mine from each of five ships every 15 seconds, 20 mines laid every minute, 100 mines in every mile of length of the field.

The flagship, or the ship on the opposite flank, usually the *Baltimore*, would be running taut wire during the minelaying, as a check on the distance over the ground, so that the minefield might be of the length intended.

After three or four hours of this, without interruption or any swerving or slackening pace, the schedule would finish with dropping a few buoys to mark the end of the field, and the now empty ships would reform compactly, to return to the base, near Inverness, to load for another excursion.

The round trip would take two or three days, according to the location of the field, and coaling and embarking another load of mines three or four days more. Thus one trip a week could have been made, had an escort and support been always available as soon as the squadron was ready, which was seldom the case. Actually the excursions by the American Squadron averaged one every ten days for five months. Altogether 8400 miles were steamed, in a total of 740 hours (31 days) under escort. There were no casualties during the minelaying and, except for one man lost overboard at sea and several deaths from ordinary causes, the squadron went through the operation with ships and personnel intact.

Definite information since the armistice (up to March 1, 1919) credits the Northern Barrage officially with the sinking of four submarines certainly, two more probably, and possibly yet two more, making a total of eight. There are reports of three others damaged, but these reached a German port in safety. The sweeping operations, which have been in full swing for many months, may establish that still more submarines came to their end in the barrage. Already there are some indications of it. Further, Admiral Sims' summary states:

> "There is no doubt that this barrage had a considerable moral effect on the German naval crews, for it is known that several submarines hesitated

> some time before crossing. Also, reports from German sources are that the barrage caused no small amount of panic in some of the submarine flotillas.
>
> "It is also probable that the barrage played a part in preventing raids on Allied commerce by fast enemy cruisers."

Other information indicates that knowledge of the barrage and its growing effectiveness had spread outside of naval circles, among the army and the civilian population.

In his article, "The Victory at Sea," Admiral Sims mentions a barrage across the North Sea, from the Orkneys to the coast of Norway, as one of the ideas suggested early in 1917 to solve the submarine problem, but it was not among the possibilities then, for lack of mines. At that time, there were not even enough mines to make a successful barrage across the Strait of Dover, only twenty miles wide.

Of the eight submarines credited to the Northern Barrage, only one was sunk prior to September 7, 1918, the date on which the barrier was extended completely across the North Sea. This leaves a toll of six or seven submarines *destroyed* during only a two months period of the barrier complete before the armistice. This indicates how many more submarines would have been destroyed or damaged, had it been permitted to carry the barrier completely across earlier, as could have been done. Much more than that, does it not indicate what decisive effect the Northern Barrage could have accomplished, had the development of mines and minelaying progressed along with other weapons, to the extent that former wars had shown to be reasonable? The probable results of such development would have been that suitable and sufficient mines and minelayers would have been available much earlier, to establish the barrage when its need first became acute, and thereby hasten by many months the end of the submarine menace.

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Errors in Coast Artillery Range Finding and Shooting with Particular Reference to the Sinuous Course

By Lieut. Col. Roger B. Colton, C. A.

I

The final error of coast artillery firing as represented by the distance the shot falls from the center of the target is made up of the sum of an infinite number of small errors.

It is my intention in the following pages to separate this final error into its components, to group those errors which are capable of group treatment, and to set up, where possible, the mathematical relations between the errors and the known constants of the coast artillery system.

Finally I wish by means of the equations thus established to compare the results attainable under the present prescribed methods with those attainable under alternative methods.

Furthermore although I shall largely confine myself to the derivation of the general formulas giving the errors of coast artillery range finding, it is necessary, in order to make real use of the formulas, to consider the errors of shooting and discuss the interdependence of range finding and shooting errors.

For purpose of illustration I have selected the problem of a mortar battery firing at a naval vessel when the vessel is pursuing a sinuous course, and the questions under consideration are:

What is the best combination of the predicting interval and observing interval?

How much effect has the sinuous course on mortar fire?

What changes are desirable in the present system to combat the sinuous course?

II

Errors in Range Finding Common to All Courses

In coast artillery firing we strive to make the position of the set-forward point coincide with the position of the target at the instant of splash. Hence, in connection with range finding the errors we wish to consider are the errors of the set-forward point with reference to the actual position of the target at the instant of splash.

It is not possible to consider each individual error, hence certain errors must be grouped.

Let us, therefore, first consider the average inherent error in the location of the set-forward point due to the instrumental errors, errors in reading, in transmission, in arm setting, in plotting, errors due to the weaving of the vessel—that is, slight unintentional weaving away from the true course due to the inability of the helmsman to "hold on." These errors I sum up and designate the algebraic mean sum, "E_s."

Now our error E_s is always present whether our course be sinuous or straight, and furthermore it is the only error present when a so-called straight course is plotted. Therefore I have taken a straight track of a vessel as plotted by a mortar battery range finding section and listed the errors of the set-forward point right and left of the course—see course 10;33;34 A.M. to 10;51;15 A.M. Figure 1—and I find these errors to be 45, 30, 0, 0, 0, 30, 50, 30, 20, 20, 20, 30, 20, 15, 20, 300, 0, 0; giving an average error of 35 yards.

I have further gone over the target practice reports of a certain seacoast mortar battery covering a period of eight years (about thirty practices) and have selected the only ones (five) in which the errors of the set-forward points are shown with respect to the target. (See Table 15.) The average error of the set-forward point with respect to the target from these reports is 37 yards.

Hence we may assume that E_s under the conditions of our standard system:

Predicting base, I, 60 seconds or two observing intervals;
Predicting interval, P, 60 seconds;
Observing interval, I, 30 seconds;
Average time of flight, T, 60 seconds; r is equal to 36 yards.

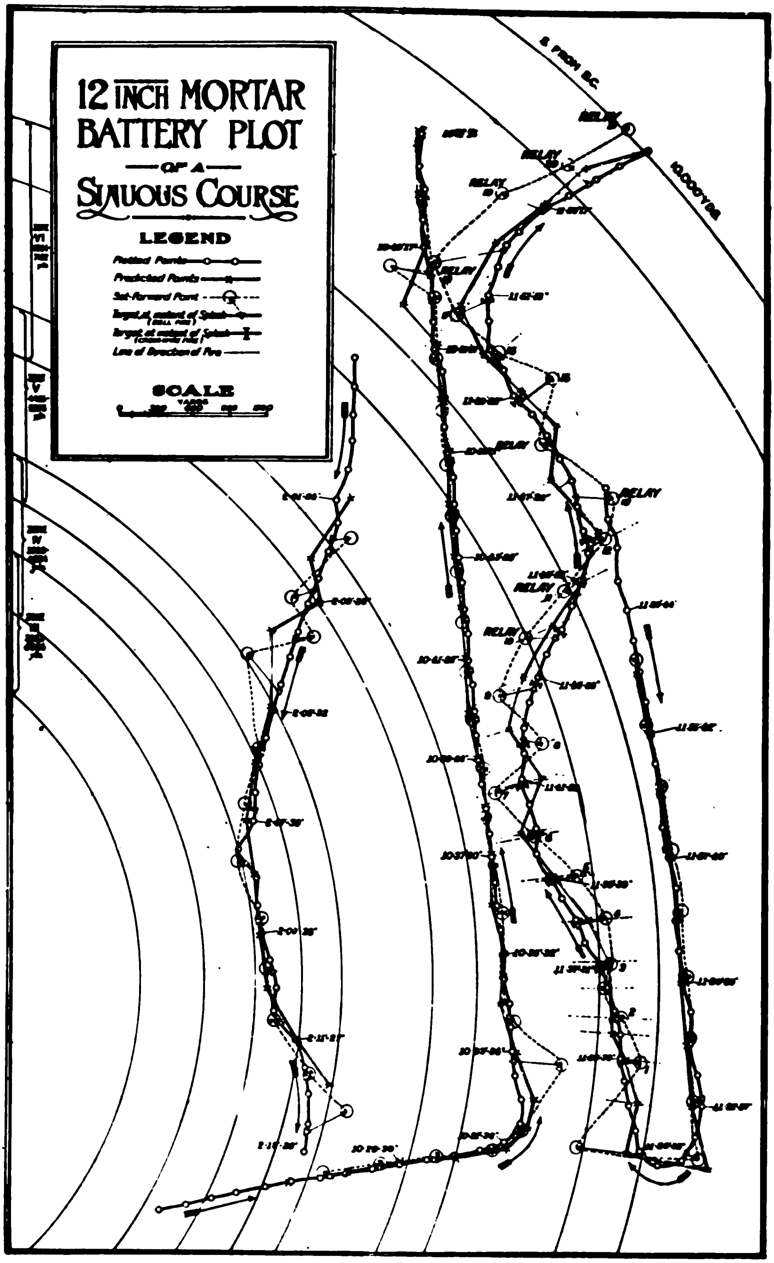
12 INCH MORTAR
BATTERY PLOT
OF A
SINUOUS COURSE
LEGEND
Plotted Points
Predicted Points
Set-Forward Point
Target at instant of Splash (BELL FIRE)
Target at instant of Splash (CONTINUOUS FIRE)
Line of Direction of Fire
SCALE
YARDS
RELAY
10,000 YDS.

FIG. 1 2467

It will be noted that the error E_s is almost entirely the result of a small error in each of the two plotted points used in the predicting base.

Now if we consider only errors right and left of the course of the vessel and designate the error of the first plotted point, second plotted point, and set-forward point as E_{x_1}, E_{y_1}, E_{s_1}, respectively:

$$E_{s_1} = E_{y_1} + (E_{y_1} - E_{x_1})\frac{P+T}{I}$$

$$I\,E_{s_1} = (I+P+T)E_{y_1} - (P+T)E_{x_1}$$

$$I^2E^2_{s_1} = (I+P+T)^2E^2_{y_1} + (P+T)^2E^2_{x_1} - 2(I+P+T)E_{x_1}E_{y_1}$$

and if there be n such points:

$$\int_0^n I\,E^2_{s_1} = \int_0^n (I+P+T)^2E^2_{y_1} + \int_0^n (P+T)^2E^2_{x_1} - \int_0^n (I+P+T)(P+T)E_{x_1}E_{y_1}.$$

If n be large, the last summation term will be zero as the individual terms will as often be plus as minus. Hence dropping last term and dividing by $\frac{1}{n^2}$:

$$\frac{1}{n^2}\int_0^n I^2E^2_{s_1} = \frac{1}{n^2}\int_0^n (I+P+T)^2E^2_{y_1} + \frac{1}{n^2}\int_0^n (P+T)^2E^2_{x_1}$$

Now if E_s = average error of set-forward point and E_p = average error of a plotted point, then

$$\frac{1}{n^2}\int_0^n E^2_{s_1} = E^2_s;\quad \frac{1}{n^2}\int_0^n E_{x_1} = \frac{1}{n^2}\int_0^n E^2_{y_1} = E^2_p$$

and:

$$I\,E^2_s = (I+P+T)^2E^2_p + (P+T)^2E^2_p$$

$$I\,E_s = \sqrt{(I+P+T)^2+(P+T)^2}\;E_p$$

$$= E_p(I+P+T)\sqrt{1+\frac{(P+T)^2}{(I+P+T)^2}}$$

The factor

$$\sqrt{1+\frac{(P+T)^2}{(I+P+T)^2}}$$

can never be greater than $\sqrt{2}$, and for mortar fire it varies from 1.20 to 1.30. Hence we make no serious error in assuming:

$$E_s = 1.25\ E_p\left(1 + \frac{P+T}{I}\right)$$

Experimentally $E_s = 36$, hence:

$$1\tfrac{1}{4}E_p = 12.$$

Obviously the average error of a plotted point will increase if the observing interval is decreased. The ratio of this increase should be determined experimentally, but lacking such data we may reasonably assume that it is of the form:

$$\frac{dE_p}{dz} = \frac{k}{z^2}, \text{ when } P = \text{constant}$$

This differential satisfies the condition that the rate of increase of the error becomes very large when the observing interval becomes small, and further satisfies the condition that when the observing interval becomes very large the error no longer materially decreases with further increase of the observing interval.

Integrating the above equation we have:

$$E_p = \frac{k_1}{z} + C_1, \text{ when } P = \text{constant.}$$

Similar reasoning will apply to the relation between the predicting interval and the error of the plotted point when the observing interval remains constant.

Hence:

$$E_p = \frac{K_2}{P} + C_2, \text{ when } z = \text{constant.}$$

Now certainly a simultaneous decrease of both the observing and predicting intervals will produce a larger error than the sum of the errors due to their separate decreases. Therefore our final equation must contain a term:

$$F = \frac{k_3}{pz}$$

Also where the predictions are not made on each plotted point, the error of the plotted point will average less because there will be less hurry and confusion. Therefore we must introduce a factor n in our equation, n being the ratio of the number of plotted points to the number of predictions.

Hence we assume the following empirical equation:

$$1\tfrac{1}{4}E_p = \frac{120}{P} + \frac{60}{z} + \frac{14{,}400}{Pzn^2} + 6.$$

This equation satisfies the following conditions:

1. $P = 0$ E_p = infinity.
2. $z = 0$ E_p = infinity.
3. $P = 60$, $z = 30$, $n = 2$, $1\frac{1}{4}E_p = 12$.
4. P = several minutes, z = several minutes, E_p = error of weaving only.

We have only considered the error of a plotted point right or left of the course of the vessel. Now if the vessel be traveling at a fairly uniform speed the error along the course will be small, and for the purposes of this discussion will be neglected.

In order to make our formulas of use we must resolve them into longitudinal and lateral values.

Then if E_2 is the longitudinal component of E_2 and e_2 is the lateral component, and Q is the average angle made by the course with a line perpendicular to the line of fire:

$$E_2 = 1\tfrac{1}{4}E_p\left(1 + \frac{P+T}{I}\right) \cos Q$$

$$e_2 = 1\tfrac{1}{4}E_p\left(1 + \frac{P+T}{I}\right) \sin Q.$$

But if crosswire fire is used as prescribed by the regulations:

$$E_2 = 1\tfrac{1}{4}(E_p) \left(1 + \frac{P+T}{I}\right) \cos Q$$

$$e_2 = 1\tfrac{1}{4}\, E_p \left(\frac{T}{I}\right) \sin Q.$$

III

ERRORS IN RANGE FINDING DUE TO THE SINUOUS COURSE

In order that we may understand the problem with which we are dealing I show in Figure 2 a sinuous course designed to enable a naval vessel to escape mortar fire. This course is designed to cover the following points:

1. The average time of flight of mortar projectiles being 60 seconds, the customary predicting interval being 60 seconds, there will certainly be from 1¼ to 2 minutes from the time of the last plotted point to time of splash. Hence the sinuous course should not oftener than absolutely necessary cross

its previous tangent at a time greater than 1¼ and less than 2½ minutes.

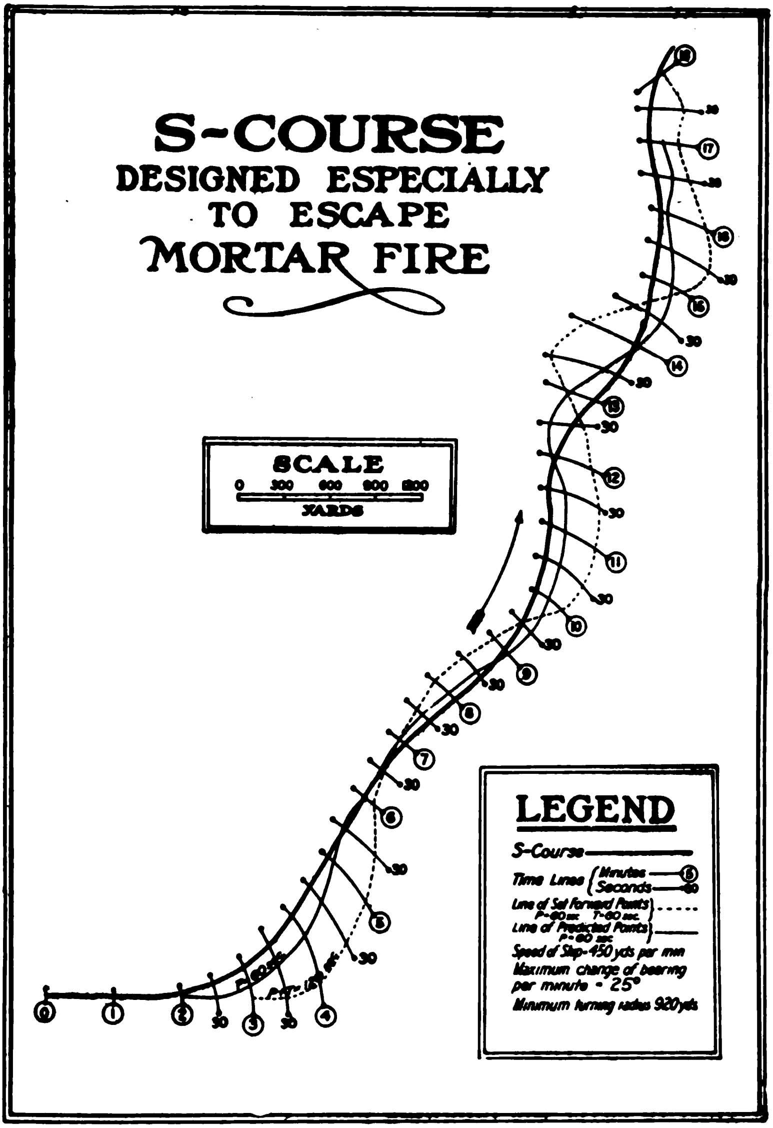
S-COURSE
DESIGNED ESPECIALLY
TO ESCAPE
MORTAR FIRE
SCALE
0 300 600 900 1200
YARDS
LEGEND
S-Course
Time Lines Minutes 5
Seconds 60
Line of Set Forward Points P-60 sec T-60 sec
Line of Predicted Points P-60 sec
Speed of Ship-450 yds per min
Maximum change of bearing per minute - 25°
Minimum turning radius 920 yds
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
30
P-60
P-T-120

FIG. 2.

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2. If the curvature of the sinuous course is usually held in one direction longer than twice the time of flight, a plotter may, by assuming the curvature as continuing, gain a possibility of more correct prediction.

3. If the curvature is uniform from period to period, the plotter may gain accuracy by assuming the curvature as constant, either continuing or reversed.

Hence the course shown in Figure 2, to meet the above conditions is designed with the elements shown in Table 1. The course has no law of turning. The plotter can only assume that the vessel will go ahead, turn right, or turn left. Hence we see that with a course similar to that of Figure 2, where there is no limitation on the course of the vessel and when the course from one predicting interval to another varies entirely by chance, the prediction on the tangent, being the mean, is the one which will give the best results to the plotter.

The error introduced by the sinuous course is divided into two parts, the first, which I will call E_r, being the error due to the fact that with a finite observing interval it is impossible to determine the true tangent to the course at the last plotted point. The plotter can only at best assume that the chord connecting two plotted points is the tangent, and if D is the average change of bearing in degrees per minute of the vessel, and S is its average speed in yards per minute, then as the chord is parallel to the tangent at a point half way between the two plotted points:

$$E_r = S\left(\frac{P+T}{60}\right)\left(\tan\frac{DI}{120}\right),$$

E_r being the average error right or left of the course of the vessel. Now, obviously, this error will appear partly as a longitudinal error and partly as a lateral error. To resolve the error into its components we merely multiply it by the sine and cosine of the obliquity of the course.

$$E_3 = S\left(\frac{P+T}{60}\right)\left(\tan\frac{DI}{120}\right)\cos Q = \text{Average longitudinal error.}$$

$$e_3 = S\left(\frac{P+T}{60}\right)\left(\tan\frac{DI}{120}\right)\sin Q = \text{Average lateral error.}$$

Q being as previously defined. However it is convenient to say

$$Q = q + \alpha,$$

where α is the angle made by the general bearing of the sinuous course with a line perpendicular to the line of fire, and q is the average angle between the instantaneous tangent and the general bearing.

For crosswire fire as prescribed in the regulations:

$$E_3 = S\left(\frac{P+T}{60}\right)\left(\tan\frac{DI}{120}\right)\cos Q$$

$$e_3 = S\left(\frac{T}{60}\right)\left(\tan\frac{DI}{120}\right)\sin Q.$$

The second part of the error introduced by the sinuous course is that due to the departure of the vessel from the tangent to its course at the last plotted point during the predicting interval and time of flight.

This average error is, with sufficient accuracy, the versine of the average angle turned during the predicting interval and average time of flight, multiplied by the average radius of turning.

Now $D\frac{P+T}{60}$ is the average angle turned,

and $\frac{360\ S}{2\pi D}$ is the average radius of turning.

Hence the average departure of the vessel from the tangent at the last plotted point is:

$$\left(1-\cos D\,\frac{P+T}{60}\right)\frac{360\ S}{2\pi D}$$

and hence:

$$E_4 = \left(1-\cos D\,\frac{P+T}{60}\right)\frac{360\ S}{2\pi D}\cos Q = \text{Average longitudinal error.}$$

$$e_4 = \left(1-\cos D\,\frac{P+T}{60}\right)\frac{360\ S}{2\pi D}\sin Q = \text{Average lateral error.}$$

Or, when mortars are fired on the crosswire instead of on the bell:

$$E_4 = \left(1-\cos D\,\frac{P+T}{60}\right)\frac{360\ S}{2\pi D}\cos Q$$

$$e_4 = \left(\cos\frac{DP}{60}-\cos D\,\frac{P+T}{60}\right)\frac{360\ S}{2\pi D}\sin Q.$$

We are now in position to calculate and tabulate the various errors to be expected in the location of the set-forward point, for any values of the predicting interval, observing interval, for any sinuous course where the speed, average obliquity, and average rate of turning is known.

In order to check our formulas we will calculate the errors of a course similar to that shown in Figure 1.

This course has the following constants:

S = 450 yards per minute.
D = 12 degrees per minute change of bearing.
q = 23 degrees, average angle between the general bearing of the course and the instantaneous tangent.
α = Angle between line of general bearing and a line perpendicular to the line of fire = 0 for broadside course, = 90 for head-on course.
Q = $\alpha + 23$ degrees. Average angle between the instantaneous tangent and a line perpendicular to the line of fire.

Further we note that the constants of the standard system are:

$n = 2$
$z = 30$
$I = 60$
$P = 60$
$T = 60$

We find on substituting the above values in the formulas deduced:-

$E_2 = 33$ yards $e_2 = 5$
$E_3 = 87$ $e_3 = 18$ Broadside Course
$E_4 = 171$ $e_4 = 54$

Hence the resulting average longitudinal error is: $E = 195$ yards,* and the resulting average lateral error, $e = 57$ yards.

When the vessel runs a course head-on to the battery,

$$Q = q + \alpha = 23 + 90 = 113 \text{ degrees}$$

Making this substitution in the formulas we find:

$E_2 = 14$ $e_2 = 11$
$E_3 = 37$ $e_3 = 43$ Head-On Course
$E_4 = 73$ $e_4 = 127$

$E = 82$ $e = 134$

To obtain the final average lateral and longitudinal errors under all conditions we may with sufficient accuracy average the values for broadside and head-on courses:

---

* Crandall, Least Squares, pages 207, 208, and 264.

$\varepsilon^2 = \varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_2^2.$ and $E = 4/5\ \varepsilon$

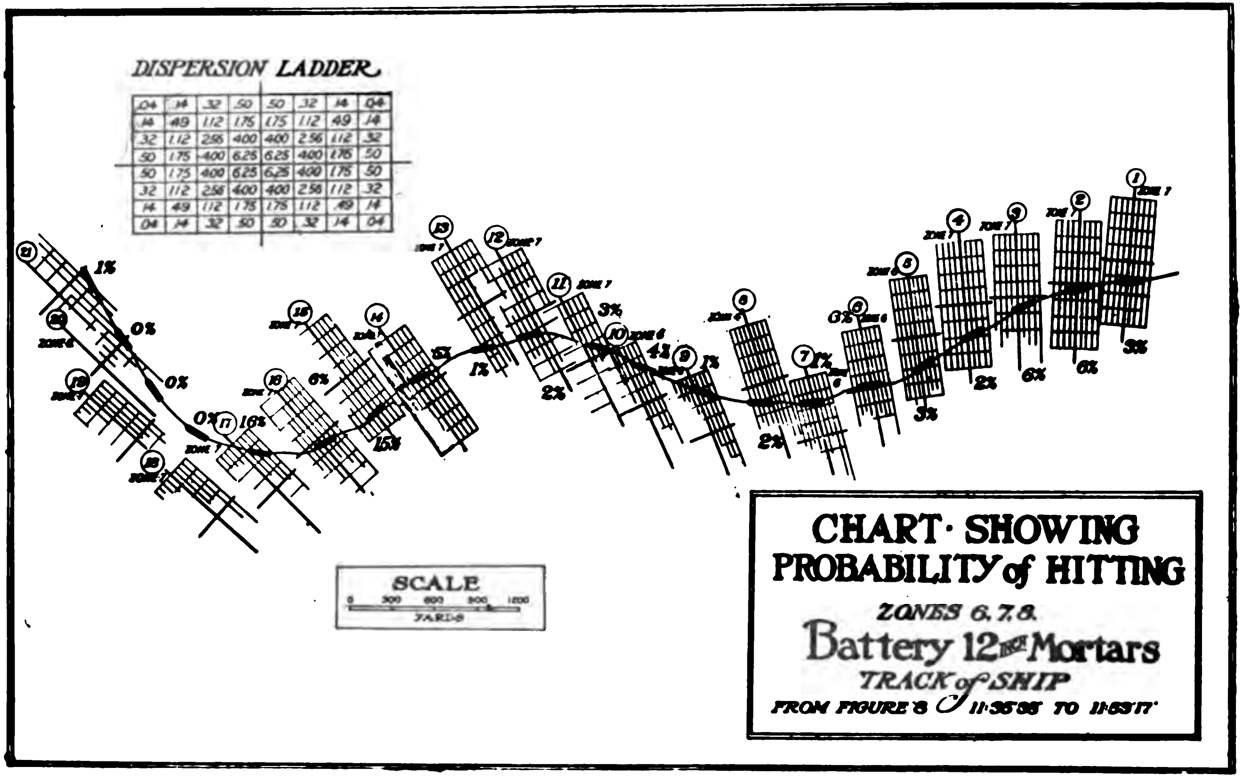

CHART · SHOWING PROBABILITY of HITTING

ZONES 6, 7, 8.

Battery 12 INCH Mortars

TRACK of SHIP

FROM FIGURE'S 8 11:36'36 TO 11:63'17

DISPERSION LADDER

.04	.14	.32	.50	.50	.32	.14	.04
.14	.49	1.12	1.75	1.75	1.12	.49	.14
.32	1.12	2.56	4.00	4.00	2.56	1.12	.32
.50	1.75	4.00	6.25	6.25	4.00	1.75	.50
.50	1.75	4.00	6.25	6.25	4.00	1.75	.50
.32	1.12	2.56	4.00	4.00	2.56	1.12	.32
.14	.49	1.12	1.75	1.75	1.12	.49	.14
.04	.14	.32	.50	.50	.32	.14	.04

FIG 3.

$$E_g = \frac{195+82}{2} \qquad e_g = \frac{57+134}{2}$$

$$E_g = 133 \qquad e_g = 95,$$ denoting the general values by the subscript g.

Actual measurement of the errors shown in Figures 3 and 1 give the values: E_g = 120, e_g = 80, which may be considered fair agreement with those deduced from theory. (The course of Figure 1 is at first broadside and lateral most head-(end) on).

IV

DETERMINATION OF THE ERRORS OF COAST ARTILLERY SHOOTING

The errors of coast artillery shooting are best determined from the records of target practice. Therefore I have turned to the target practice reports of a mortar battery and have selected the ones in which the results were tabulated in the desired manner. A partial summary of these reports is given in Table 15. The errors of shooting with respect to the set-forward point are plotted and adjusted in Figure 4. The errors of trial shots with respect to the center of impact are also plotted and adjusted in Figure 4.

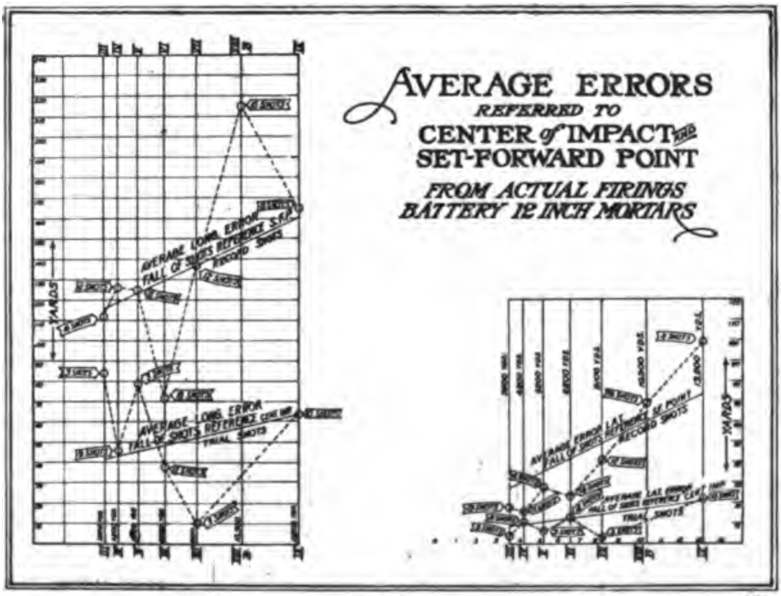

FIG. 4.

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It will be noted that the various errors for mortars with our standard system can be sufficiently accurately expressed by the following empirical equations:—

$$B = 100 + \frac{R}{200} \qquad b = 10 + \frac{R}{200} \quad \text{for record firing}$$

$$M = 30 + \frac{R}{400} \qquad m = 5 + \frac{R}{800} \quad \text{for trial shots}$$

where:

B = Average longitudinal error of record practice shooting reference set-forward point.
b = Average lateral error of record practice shooting reference set-forward point.
M = Average longitudinal error of trial shot shooting reference center of impact.
m = Average lateral error of trial shot shooting reference center of impact.
R = Range in yards.

In the case of the range finding error we were able to tabulate and calculate the value of certain of its components. To a certain extent this may be done with the shooting error. I will indicate the sub-errors of mortar shooting at 7000 yards for the longitudinal errors only.

B = 135 as shown above. B is composed of the following sub-errors:
B_1 = 28 = Error in determination of the center of impact due to use of a finite number (three) of trial shots.
B_2 = 54 = Personnel errors from time set-forward point is marked on plotting board until splash occurs.
B_3 = 48 = Armament error = M.
B_4 = 110 = Error due to change of atmospheric conditions between time of firing trial shots and record shots.

The above values are determined as follows:
$B_1 = M\sqrt{3} \qquad 48\sqrt{3} = 28$ yards.

B_2 can be ascertained by deducting the armament error from the average longitudinal error of the record series with respect to the center of impact of the shots. Tabulating this value for nine practices I find the mean longitudinal errors with respect to the center of impact to be: 57, 45, 80, 92, 61, 26, 26, 191, 70. Hence averaging these values we find,

$$\text{Average} = \frac{648}{9} = 72 \text{ yards.}$$

The armament error is merely the trial shot error, $M = 48$. Hence $(48)^2 + B^2_2 = (72)^2$, whence $B_2 = 54$ yards.

Likewise, $B^2_4 + (54)^2 + (48)^2 + (28)^2 = (135)^2$

$B_4 = 110$ yards.

Now at this point we note that the major error of mortar shooting is the atmospheric error. Thus, if the personnel error be increased by 50%, from 54 to 81 yards, the average shooting error will only be increased by 10%, to 148 yards. And, on the other hand, a 50% increase in the atmoshperic error corresponds to a 45% increase of the shooting error.

The value, 110 yards, of the longitudinal error due to change of atmospheric conditions seems large when compared with the lateral shooting error of 45 yards, but it must be remembered that our method of fire on the crosswire shifts a portion of the wind error from deflection to range, and also corrections for deflection are usually easily made, and are habitually made.

V

INTERDEPENDENCE OF RANGE FINDING AND SHOOTING ERRORS

The range finding error has been defined as the error of the set-forward point with respect to the actual position of the target at the instant of splash.

Similarly, of course, the shooting error is the error of the splash with reference to the set-forward point.

These errors are not independent in coast artillery fire, for the reason that the range finding and shooting sections share the predicting interval in performing their duties. The longer the range finding section takes to locate the set-forward point, the less time remains for the shooting section to compute elevation and corrections, and lay the mortar.

It will be noted that for the purpose of this article the range finding section is only that part of the fire control section concerned with the actual location of the set-forward point. Thus in a mortar battery the plotter when he reads the range to the set-forward point is acting as a member of the shooting section, and the elevation and deflection computers are as much members of the shooting section as the azimuth setter on the mortar.

VI

MODIFICATION OF THE CONSTANTS OF THE STANDARD COAST ARTILLERY SYSTEM

It has been shown that, for instance, at a range of 7000 yards the shooting eror of the standard system is 135 yards. Now, if a vessel be pursuing a straight line course, our standard system will yield an average longitudinal range finding error of $E_g = \frac{36+0}{2} = 18$ yards in the location of the set-forward point.

Hence we should expect a total average error of splash with respect to the target to be the square root of the sum of the squares of these errors, or 136 yards.

In other words the slight increase of error of the shot with respect to the target does not warrant further refinement of location of the set-forward point. However when dealing with the sinuous course the case is quite different.

Here we have:

$E_g = 133$ yards, $B = 135$ yards, and the mean longitudinal error of shot with respect to the target

$$\sqrt{(133)^2 + (135)^2} = 190 \text{ yards.}$$

Thus we see the immediate effect of the sinuous course is to increase the range error by 40% over that of a straight line course. Similarly the lateral error of splash with respect to target is increased from 49 yards straight line course, to 110 yards sinuous course, an increase of 114%.

Theoretically this should decrease our probability of hitting at this range from 6% to 2%. By actually placing dispersion ladders on the set-forward points 1 to 21 of the course shown in Figure 1 (see Figure 3), we find that the average probability of hitting is 2.35%, which substantially checks the deduced results.

In the case of the straight line course the small value of the range finding error with relation to the shooting error indicated that further improvement on that course must come from reduction of the shooting error, even though the range finding error be increased thereby.

However with the sinuous course we are faced with more nearly equal errors of range finding and shooting, namely:

$E_g = 133$ $e_g = 105$
$B = 135$ $b = 45$

Hence one error must be decreased without great expense to the other.

It has been seen that the errors of range finding when dealing with the sinuous course are functions of P, I, and T.

The table below shows the effect of certain modifications of P and I on the range finding errors.

RANGE FINDING ERRORS
SINUOUS COURSE

$S = 450$ yds. per minute
$D = 12°$ Change of bearing per minute (average)
$T = 60$ Seconds, time of flight (average)
$Q = q + \alpha$ $q = 23°$

Target: Broadside, $\alpha = 0°$

	Z	N	I	P	E_2	E_3	E_4	E	e_2	e_3	e_4	e
Standard System	30	2	60	60	33	87	171	195	5	18	54	57
1st Modification	30	1	30	60	103	32	97	145	22	9	36	42
2nd Modification	45	1	45	30	63	49	97	126	13	14	36	40
3rd Modification	30	2	30	30	59	32	97	118	13	9	36	39

Target: Head-on, $\alpha - 90°$

	E	e
Standard System	82	134
1st Modification	62	99
2d Modification	52	93
3d Modification	50	92

General Errors—Average of Broadside and Head-On Values

	E_g	e_g
Standard System	133	95
1st Modification	103	70
2d Modification	89	66
3d Modification	84	65

The modifications as listed are:

1. Doubling the speed of the standard system. 30-second predictions every 30-seconds. 30-second observing interval and predicting base. Increase of range finding accuracy 45 per cent.
2. Thirty-second prediction every 45 seconds. 45-second observing interval and predicting base. Increase of range finding accuracy of 55 per cent.
3. Thirty-second prediction every 60 seconds. 30-second observing interval and predicting base. Increase of range-finding accuracy of 59 per cent.

The advisability of adopting any of these modifications will depend on their effect on the shooting error. Of the three modifications it is seen that the third will have the least effect on the shooting error, for here the only variation from the standard system that effects the shooting error is the reduction of the predicting interval from 60 to 30 seconds.

But it is also seen that our formulas allow in this modification a 59 yard longitudinal and 13 yard lateral error in the location of the set-forward point due to inaccuracies of the personnel, instrumental errors, weaving, etc. (E_2 and e_2).

Let us assume then that at time zero the readings are taken; point plotted at time 4; set-forward point located at time 9; range and azimuth read at time 11; elevation and corrected azimuth computed at time 14; data received in pits at time 15; mortars laid at time 25; fired at time 30.

This schedule is fast but it can be met if we eliminate all non-essential refinements such as the use of predictors (depending on the eye alone for prediction), plotting of the predicted point, and checking of azimuth and elevation after laying.

It is quite possible that the elimination of these refinements will increase the shooting error, but not materially, for it has been previously shown that even if the sub-error of shooting due to personnel errors is increased by 50 per cent it will on the average only increase the shooting error by 10 per cent.

Then if the third modification is adopted we may finally expect a net increase of the probability of hitting the sinuous course from 2 per cent to 4½ per cent which compares not so unfavorably with the probability of hitting, 6 per cent, on a straight line course.

IX

CONCLUSION

We have now completed a detailed and rather dry investigation of the errors of coast artillery mortar fire. There are a number of salient points which may well be presented to the eye stript of the figures and symbols which hide them in the preceding pages.

We notice that the coast artillery system of mortar range finding which has been built up with such care during the past twenty years is a good system. Its error is almost negligible when dealing with the straight line course—and that is the course it was developed to meet—and with a slight modification it will give good results against a sinuous course.

In our shooting we find the controlling factor to be the wind. But I understand that plans now underway will enable us to eliminate the wind error very largely, and if this be the case we may expect to increase our probability of hitting on a straight line course from two to three times its present value.

In dealing with the range finding error of the sinuous course we find that roughly speaking the error increases directly as the square of the sum of the predicting interval and time of flight. We find it advisable to reduce the predicting interval to the minimum consistent with fair care in computing data and laying the mortars.

So far as change of methods and equipment is concerned it may be pointed out that our present system of plotting three sets of points (plotted, predicted, and set-forward points) is unwieldy and unneccessary. Our purpose would be as well served by plotting the set-forward point only. This will best be accomplished by adding a travel device to our observing instruments so that the travel of the target may be added to the readings of the base end instruments and deducted from the setting of the battery commander's instrument, or vice versa.

What has been said in the previous pages with reference to mortar fire on the sinuous course applies as well, but in less degree to rifle fire. A study of rifle fire on the sinuous course shows that at extreme ranges, or whenever the time of flight is large, it is extremely advisable to reduce the predicting interval to the minimum.

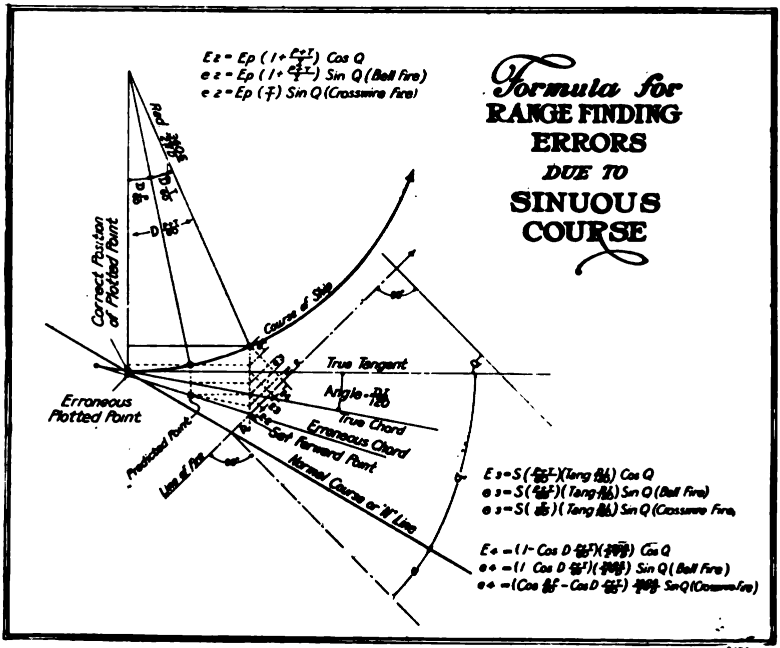
Formula for RANGE FINDING ERRORS DUE TO SINUOUS COURSE
Ez = Ep (1 + P+T/T) Cos Q
e z = Ep (1 + P±T/T) Sin Q (Bell Fire)
e z = Ep (∓) Sin Q (Crosswire Fire)
Correct Position of Plotted Point
Erroneous Plotted Point
Course of Ship
True Tangent
Angle
True Chord
Erroneous Chord
Set Forward Point
Predicted Point
Line of Fire
Normal Course or "N" Line
E3 = S (Tang) Cos Q
e3 = S (Tang) Sin Q (Bell Fire)
e3 = S (Tang) Sin Q (Crosswire Fire)
E4 = (1 - Cos D) Cos Q
e4 = (1 Cos D) Sin Q (Bell Fire)
e4 = (Cos - Cos D) Sin Q (Crosswire Fire)
9471

FIG. 6.

APPENDIX

TABLE 1*

Course of Figure 2

Helm	Time Minutes	Degrees Turned Per Minute	18 Knot Ship Radius of Curvature Yards	12 Knot Ship Radius Yards	24 Knot Ship Radius Yards
Neutral	1½	0			
Starboard	2½	21	1650	1100	2200
Neutral	2	0			
S	2	10	3450	2260	4520
P	3½	15	2300	1530	3060
S	1½	25	1380	920	1820
P	1¼	20	1730	1150	2300
S	1	5	6900	4600	2900
S	1	15	2300	1530	3060
P	1¼	25	1380	920	1820

The rate of turning, etc., is the same as for Course in Figure 1.

TABLE 15

August 26, 1914. Battery 12" Mortars

RECORD SHOTS—LONGITUDINAL ERROR

Range Set-Forward Pt.	Range Target	S.F.P. Reference to Target	Shots fell Reference to Target	Shots Fell Reference to S.F.P.
		Zone 6		
6600	6530	70	53	17
6600	6530	70	191	121
6550	6470	80	88	8
6550	6470	80	133	53
6380	6330	50	180	130
6380	6330	50	36	86
		400		69.2
		Zone 5		
5910	5970	60	105	45
5910	5970	60	176	116
5890	5900	10	88	78
5890	5900	10	145	135
5890	5890	0	150	150
5890	5890	0	223	223
		140		124.5
August 28, 1914.		Battery	12" Mortars	
		Zone 4		
4460	4620	160	207	367
4540	4540	0	125	125
4540	4540	0	155	155
4500	4490	10	274	264
3930	3920	10	35	45
		180		191.2
August 28, 1914.		Battery	12" Mortars	
		Zone 3		
3670	3670	0	256	256
3670	3670	0	214	214
3560	3560	0	140	140
3560	3560	0	15	15
3540	3535	5	35	40
3540	3535	5	11	6
3430	3440	10	195	205
		20		125.

TABLE 15—Continued

RECORD SHOTS—LONGITUDINAL ERROR

Range Set-Forward Pt.	Range Target	S.F.P. Reference to Target	Shots fell Reference to Target	Shots fell Reference to S.F.P.
August 18, 1915.		Battery	12" Mortars	
		Zone 4		
4310	4250	60	182	122
4310	4250	60	189	129
4280	4130	150	127	23
4280	4130	150	143	7
4270	4150	120	192	72
4270	4150	120	114	6
		660		69.8
		Zone 3		
3690	3710	20	122	142
3690	3710	20	155	133
3730	3730	0	45	45
3730	3730	0	43	43
3780	3780	0	105	105
3780	3780	0	118	118
		40		98.
August 26, 1915.		Battery	12" Mortars	
		Zone 7		
7751	7871	120	76	44
7751	7871	120	128	8
7471	7471	0	143	143
7471	7471	0	128	128
7240	7240	0	185	185
7240	7240	0	108	108
		240		102.7
		Zone 6		
6820	6820	0	47	47
6820	6820	0	6	6
6620	6620	0	1	1
6620	6620	0	11	11
6580	6520	60	17	77
6580	6520	60	27	33
		120		29.1

TABLE 15—Continued

RECORD SHOTS—LONGITUDINAL ERROR

Range Set-Forward Pt.	Range Target	S.F.P. Reference to Target	Shots fell Reference to Target	Shots fell Reference to S.F.P.
May 22, 1916.		Battery		12" Mortars
		Zone No. 7.		
8280	8200	80	18	98
8280	8200	80	75	5
7990	7940	50	720	670
8400	8370	50	106	156
8530	8510	20	67	47
8530	8510	20	70	50
		300		171.
		Zone No. 6.		
6060	6090	30	216	180
6060	6090	30	121	180
6040	6040	0	0	0
6040	6040	0	38	38
6020	5975	35	69	104
6020	5975	35	164	199
		130		116.8

The errors of the set-forward point with respect to target (straight line courses) are therefore

$$(400—140—180—20—660—40—240—120—300—130) = 60 = \frac{2230}{60} = 37 \text{ yards.}$$

These are the only ones of the reports of firing of this battery from which it is possible to determine the error of the set-forward point. This mean error (37 yards) includes plotting error, instrumental errors, "weaving," and unintentional speed variations of vessel, etc. Courses were practically broadside to battery.

Practical Interior Ballistics*

By Harold G. Manning, S.B., LLM. M.P.L.

PART III

LOSS OF MUZZLE VELOCITY DUE TO EROSION

1. The purpose of Part III is to discuss the effect of *erosion* upon the muzzle velocity of a projectile fired from a cannon. A study has been made of the available literature and firing records on the subject with a view to finding the best mathematical formulae for predicting the loss of velocity to be expected for any given age of a gun. No attempt will be made to discuss the causes of erosion or methods for reducing it. This article will be chiefly confined to presenting the best known *formulae* (a) for the rate of erosion, and (b) for the rate of velocity loss. A few illustrations will then be given, taken from actual firing records.

2. *Formulae for Wear of Rifling*:—It is well known that the *wear*, or erosion of the rifling in a cannon, depends on many different factors, the most important being weight of charge, maximum pressure developed, and caliber of the cannon. The amount of erosion at any given age of the cannon may be determined by actually measuring the increase in the diameter of the bore. This measurement of the diameter of the bore is commonly made by "star-gauging"; and a comparison of star-gauge records at any time in the life of the cannon shows directly the wear produced by the firings. The following formula which has given uniformly satisfactory results in naval guns from the 5″ to the 14″, has been often used to predict the rate of erosion in any type of gun. (See Naval Ord. Pam. 412. p. 19).

$$y = A\left(\frac{\omega}{d}\right) \quad .75P^2$$

where y = increase in diameter of lands per round
A = a constant
ω = wt. of charge
d = diameter of bore
P = Maximum pressure.

Now if we assume the relation $P = (\omega)\alpha 1$, to be true as is abundantly confirmed by experiment (see Part II), the above formula becomes: $y = K_{\omega}\ .75+2\alpha$, (for any given cannon) where K and α, are constants depending on the ballistic conditions of the gun. In Part I a list of experimental values of α 1, has been tabulated for 30 different guns, mortars, and howitzers. A similar table is also given showing the *theoretical* values of the constant α 1, for 25 cannon. Assuming an average value of 2.0 for α 1, (see Table I), the formula may be put into the form:

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$$y_1 = y_0\left(\frac{\omega_1}{\omega_0}\right)\ \frac{19}{4}$$

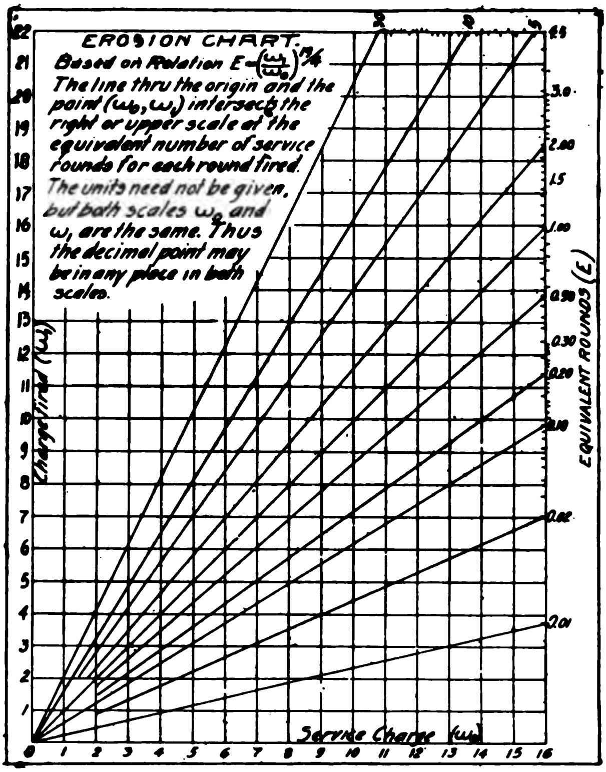

FIG. 7.

where y is the wear to be expected when any charge ω_1, other than the normal charge ω_0 is used, y_0 being the normal wear. This is the same formula recommended by the Naval Proving Ground (See Notes on Effects of Erosion, April 1916).

The above formulae may be safely used to give the rate of erosion for the early part of the life of the gun. As firing is continued, the rate probably decreases slightly owing to the lower maximum pressure and velocity.

3. *Formula for "Equivalent Service Rounds."* From the formulae in paragraph 2, the following expression is evident:

$$N_1 = N_0\left(\frac{\omega_1}{\omega_0}\right).752+\alpha_1$$

where N_0 = actual number of rounds; N_1 = Equivalent number of rounds; ω_0 = normal charge; ω_1 = charge other than normal. Taking α_1 as 2, the exponent becomes 19. Using this exponent, the accompanying chart shown in Fig. 7 was devised, and this chart has been found of great aid in computing the number of *equivalent service rounds*, in actual practice. By means of this chart (prepared by Sergt. Roman) an accurate record may be kept of the number of estimated equivalent service rounds in all guns fired.

4. *Formulas for loss in Velocity.* The following two formulae, which show the decrease in *velocity* due to erosion, will enable fairly accurate predictions to be made in the absence of actual velocity firings:

(a) $V = \frac{K}{100} N_1$ where V = loss of velocity; K = loss in f/s per 100 rounds; N_1 = equivalent service rounds.

(b) $V = 100\ K_1 y$ where y = wear in inches at 1″ from start of rifling; K_1 = loss in f/s per .01″ wear.

The determination of the constants K and K_1 for the above formulae (a) and (b) is a simple matter. This has been done for eight sets of firings as shown in the following Tables VI, VII, and VIII.

TABLE VI

EROSION IN BRITISH GUNS*

Gun	Gun No.	Velocity	No. Equiv. Rounds	Diameter 1″ from start of rifling	Wear ∠V	∠N	y	K	K_1
				inches				loss in f/s per 100 rds.	loss in f/s per .01″ in wear
4″ B.L. Mk VII British	1198 (new)	2760	112	4.032	...	...	...		
	1171 (1/3 worn)	2712	..	4.098	.048	..	6.6	..	7.27
	730 (2/3 worn)	2624	910.3	4.149	.136	798.3	11.7	17	11.60
6″ Q.F. Guns British	503 (new)	2153	11	6.015	..	..	..	..	..
	607 (1/3 worn)	2053	447	6.132	.100	336	11.7	29.7	8.45
	782 (2/3 worn)	1977	1545	6.231	.176	1534	21.6	11.5	8.15

* H. M. S. *Excellent*. "High Angle Trials."

TABLE VII

EROSION IN AMERICAN 75 M/M GUNS

Gun No.	Condition of Gun	Velocity	No. Rds.	y Wear in lands 1.19″ from start of rifling	Loss of Velocity	Mean rate of loss of Velocity	
						f/s per 100 rds.=K	f/s per .01″ wear=K_1
71	..	1704	7994	.044	53	.66	12.1
				Wear at .63″ from start			
368	good	1705	344	.006 ..	..	..	..
44	fair	1691	2895	.023 .017	14	.55	8
53	bad	1642	5780	.062 .056	63	1.16	11

TABLE VIII

EROSION IN NAVAL GUNS

Gun	Mean rate of loss of velocity	
	f/s per 100 rds.=K	f/s per .01 wear=K_1
5″/51	40	..
12″/45	100	5.3
12″/50	130	..
14″/45 (a)	30	5.5
(b)	..	2.3

From the foregoing tables it will be seen that the value of K_1 in formula (b) is less sensitive than K in formula (a). Thus K_1 only varies from 2.3 to 12.1 in all of the ten determinations, while K varies from .55 to 130. It is believed, however, that formula (b) is more accurate, and it is therefore to be preferred. To use this formula (b) to predict the velocity loss, however, a star gauge record of the lands at 1 inch from the start of the rifling must be secured. This measurement presents no difficulties provided an accurate instrument is available. If not available, recourse must be had to the less accurate formula (a) by which the prediction may be made from a knowledge merely of the number of rounds fired and the constant K for the gun. Note:-If greater accuracy is desired, the parabolic formulae $V = 100\ K_2N^r$ and $V = 100\ K_3y_1^r$ should be used—see Naval Pamphlet before referred to. In these formulae K_2, K_3, r and r_1, are constants which must be determined for each gun.

5. *Effect of Erosion on Seating*: One effect of the wear due to erosion is that the seating gradually increases during the life of the cannon and consequently the chamber volume becomes progressively larger. In separate loading guns, this change in seating accounts for nearly all of the loss in velocity. In such guns it will probably be most accurate to estimate the velocity of the basis of seating alone, as seating can be quite easily and accurately measured.

In guns using *fixed ammunition*, however, the seating remains practically constant. Hence in such guns the formulae based either on the number of equivalent rounds or on the enlargement of the diameter of the lands should be used.

6. *Effect of Erosion upon Range*: It is interesting to compare the loss of range due to erosion with the loss calculated from the observed loss in velocity. Such a comparison has been made using the results obtained in the British 4″ BL Mark VII Gun. The results are given in the following Table IX.

TABLE IX—4″ BL MK VII GUN

Gun No.	Velocity	%Loss in range	%Loss in range due to loss in MV	Prop. of loss of range due to loss of velocity.
1198	2760	1.7	1.5	89%
1171	2712	3.55	3.2	90%
730	2624	7.15	6.5	91%
				mean 90%

It is seen from the foregoing table that the loss in velocity caused by erosion accounts for nearly all of the loss in range in the above instances (i.e. 90%). Though slight in the above cases, large discrepancies may be found between the actual loss in range and that calculated from the loss in velocity. One cause of such discrepancies is the varying degree of stability of the projectile caused by the dependency of "balloting" in the bore upon the play between the bourrelet of the projectile and the surface of the lands. Another is the actual decrease for rotational velocity occurring when the band partially or completely strips.

A still further cause of discrepancies is the change in the condition of the rotating band. The enlargement of the bore due to erosion results in gradual stripping of the band and a correspondingly decreased *effective* diameter of the band. The consequent less air resistance in flight would tend to cause an increase in range.

In most cases, however, the band is so scored or fringed by the worn rifling that an increased air resistance is produced which overbalances any effect of reduced diameter.

7. *Conclusions*: Three types of formulae have been given for the prediction of the effect of erosion on velocity, one based on the number of *rounds* fired in the gun, another based

on the actual *wear on the lands* at a point 1″ from the commencement of the rifling and the third on the increased *seating.* The latter formula is probably the most accurate for separate loading guns. For fixed ammunition either of the first two types may be used. The second type is preferred if star-gauge records are available. If not available the first formula can be relied on to give fair predictions of the erosion loss of velocity. A new form of chart has been constructed whereby equivalent service rounds may be readily determined for any firing conditions which may occur in practice.

Part IV

EFFECT OF TEMPERATURE OF POWDER ON VELOCITY AND PRESSURE

1. Among the many causes of dispersion in artillery fire, one of the more serious is variable powder temperature. The magnitude of the effects produced by even comparatively slight deviations in temperature is rarely appreciated. As a matter of fact, any substantial variation in powder temperature from standard, has a marked effect upon the velocity of the projectile as it leaves the cannon, often resulting in ranges which differ greatly from those given by range tables prepared for standard conditions. An example of the magnitude of the temperature effect will illustrate this point. Thus the error in range (at maximum elevation) due to a variation of 10°F. from standard temperature, is roughly estimated to be as follows:

75 m/m Gun	240 feet		73 meters
4.7″ Gun	190 feet		58 meters
155 m/m Gun	370 feet	or	113 meters
8″ Gun	430 feet		131 meters
14″ Naval Gun	1880 feet		570 meters

An inspection of this table will show at once how great this temperature effect is. The necessity of having accurate correction methods to compensate for the effects produced by variable temperature is therefore evident.

2. It will be shown that methods now in use are defective and the advantages of a new and simple formula which has been developed will be presented. The main purpose of this part is to discuss an improved method for predicting accurately the effect of temperature variations on

velocity. Knowing the difference produced in *velocity*, it will then be possible to compute accurately the resultant effect upon the *range* or point of impact. This latter computation is more properly a matter of exterior ballistics, and is fully explained in any of the various books on the subject. In this article it will be shown that the temperature correction method commonly in use is untrustworthy, and a simple empirical formula will be presented as a substitute. This new formula will be shown to be quite accurate and at the same time to have the advantage of simplicity and convenience of use.

By means of this empirical formula (or a table constructed therefrom) it will be possible in the future to predict velocity changes due to variations in temperature, with more accuracy than has been the case in the past. By making use of this method it is believed that the artillery officer will be enabled to reduce dispersion and thus secure greater accuracy of fire.

The effect of the powder temperature on the *maximum pressure* in the gun will also be considered in this article. An empirical formula for prediction of *pressures*, similar to the velocity formula, will be presented. The pressure formula will be of especial value in cases where the pressures are large i. e. near the maximum allowed in the gun, as for instance when *excess charges* are used. On extremely hot days, when firing such *excess charges* it is evident that great care must be exercised to keep the pressures within safe limits, and it is believed that the use of this pressure formula will aid considerably in this respect.

TEMPERATURE FORMULA FOR VELOCITY NOW USED

3. The most generally adopted formula is that of *Hamilton*. This formula is in close agreement with the old Ordnance Board formula obtained about fifteen years ago when the effect of temperature on velocity was first taken into account in powder testing. Hamilton's formula is:

$$\frac{\Delta V}{V} = \frac{1}{1177}\left(2^{.032\,T} - 2^{.032 \times 70}\right)$$

where V = velocity
ΔV = change in velocity from 70°
T = temperature in Fahrenheit.

This formula has been put into the form of a table which is shown in Ordnance Pamphlet 1872 and in the handbook of the 3″ Field Gun. A table similar to the foregoing is also given in Artillery Circular M, page 231.

For some time this formula and the tables derived therefrom have been known to give inaccurate results on some guns and in view of this fact and of the clumsiness of the formula it has long been desired to put into service a better method of correction.

4. In determining a formula for use in an improved correction method, the following axiom was recognized:

The *simplest* possible formula should be used which will give results of sufficient accuracy. Hence, the following very simple formula, which has been used by Feuille was adopted:

$$\Delta V = \frac{V\Delta T}{K}$$

$$\text{or} \quad \log_{10} V = \left(\frac{1}{2.3K}\right)T$$

where V = velocity
ΔV = increase in velocity
T = temperature
ΔT = increase in temperature
K = a constant.

This formula has been found in practice to give quite reliable results. The value of the constant K should be determined for each cannon, and if this is done, the results will naturally be far more accurate than if a single "blanket" formula is assumed to hold for all guns as is the case with the previous formulae now in use.

EMPIRICAL FORMULA FOR PRESSURE

5. A similar formula for predicting changes to be expected in *pressure* due to temperature variations may also be used. This formula is $\frac{\Delta P}{P} = P\frac{\Delta T}{K}$ or $\log_{10} P = \left(\frac{1}{2.3K_1}\right)T$, and it has also been found to give reliable results.

DETERMINATION OF CONSTANTS IN EMPIRICAL FORMULAS

6. The best value of the constants K and K_1 for the formulae given in paragraphs 4 and 5 for any particular gun, can be easily obtained provided only that a set of temperature-velocity and temperature-pressure records for that gun is

available. The preferred method of determining K and K_1 consists in plotting on a suitable chart the values of *log V* and *log P* against the respective values of *T* for the particular set of data at hand. The *slopes* of the lines best representing the plotted points of the log V-T and log P-T data will then give directly the value of $\frac{1}{2.3K}$ and $\frac{1}{2.3K_1}$ respectively. From these values K and K_1 can be readily determined.

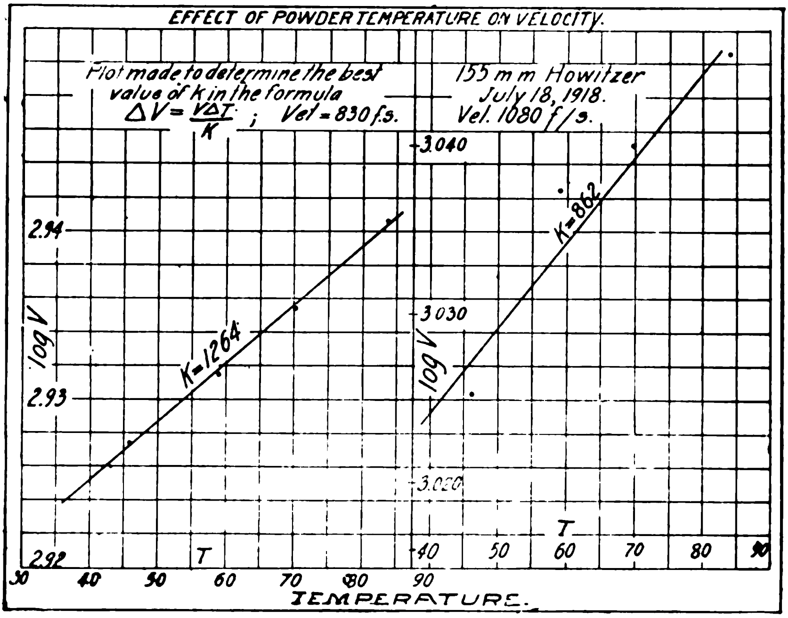

FIG. 8.

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7. In order to illustrate the inaccuracy of the old formula given in paragraph 2 and the advantages of using the simple empirical formula explained in paragraphs 3 and 4, it was desired to apply these formulas to the same experimental data and compare the results. Unfortunately very little accurate data on the subject is available. Six sets of fairly reliable data from five different guns were, however, found among firings carried out with velocities ranging from 830 to 2800 f/s.

The constants for each of the six sets of temperature data were determined by the methods given in paragraph 5. The results have been tabulated in Table X which follows and are also shown on the accompanying graphs. (See Figs. 8 and 9).

TABLE X

Temperature coefficients for Velocity and Pressure.

Gun	Weight of projectile	Weight of Charge	Chamber Volume	Normal Vel.	K	K_1	Percentage increase in velocity for 10° F
	lbs.	lbs.	cu. in.	f/s			
3" A.A.	15	5.1	200	2600	1215	970	.82
4.7 Gun	45	7.4	251	2050	1044	448	.9
5"-5 cal.	60	22.4	...	2600	1264	499	.79
155mm. How. Zone 4	95	3.6	425	830	1264	449	.79
155mm. How. Zone 5	95	5.1	425	1082	1462	375	.68
8"-45 cal.	260	100	...	2700	1630	592	.61

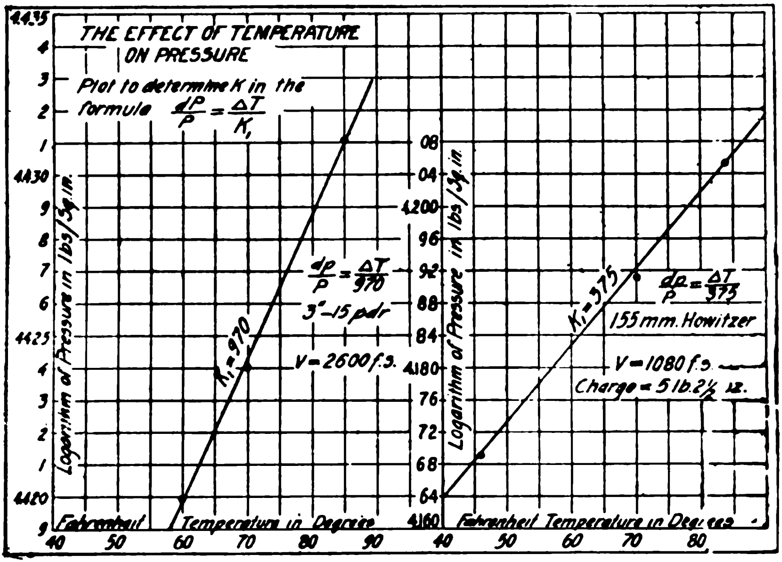

FIG. 9.

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It will be seen from an inspection of Table X, that the values of K and K_1 are by no means constant, but vary considerably from gun to gun. Moreover, even in the same gun as in the case of the 155 Howitzer, the constants are different in the lower zone from their values in the higher zone. Instead of remaining at a fixed value as does the coefficient of the old formula given in pamphlet No. 1472, the coefficient K varies all the way from 1044 to 1630. Likewise K_1 varies from 375 to 970. It is clear therefore that a rigid table, or formula, which does not take account of possible variations in the coefficient due to different ballistic conditions, is useless for accurate work.

In Table XI which follows, a comparison is given of the temperature deviation predicted by the old table with the actual observed deviations. By means of the constants K as determined for each gun from the data in Table X, the temperature deviations were then computed by the empirical formula. These deviations are shown in a third column.

TABLE XI.

Temperature-Velocity Coefficients

Comparison of Empirical Formula* with Table in Pamphlet No. 1872

155 How. V(70°) =862				155 How. V(70°) =1097		
	ΔV			ΔV		
Temp.	Obs.	Calc. K = 1264	Table	Obs.	Calc. K =862	Table
46	−16	−16	−17	−3	−34	−19
59	− 8	−7.5	− 8	−7†	−14	−10
70	0	0	0	0	0	0
84	10	10	14	14	17	16

4.7 Gun V(70°) =1996				3″ A.A. V(70°) =2521			
	ΔV				ΔV		
Temp.	Actual	Calc. K = 1044	Calc. by Table	Temp.	Obs.	Calc. K = 1215	Table
43	−49	−52	−38	45	−58	−52	−44
59	−29	−21	−18	60	−40†	−21	−22
70	0	0	0	70	0	0	0
83	19	25	29	85	5†	31	24

5″ 50 Cal. Gun V(70°) =2628				8″ 45 Cal. V(70°) =2678			
	ΔV				ΔV		
Temp.	Obs.	Calc. K = 1264	Table	Temp.	Obs.	Calc. K = 1630	Table
34.7	−63	−73	−59	45.7	−33	−40	−46
61.6	−15	−17	−20	70	0	0	0
70	0	0	0	90	46	33†	62
90.5	36†	43	62	122	95	85	231
91.0	57†	44	65				
121.1	113	104?	227				

* $\Delta V = \frac{V}{K}(T-70)$

† Data inaccurate

From an inspection of Table XI, it is seen that the results of the empirical formula are generally in close agreement with the actual observed deviations. The results computed from the table on the contrary are generally very poor, indicating conclusively the inapplicability of the old table and formula upon which it is based. It is possible that the old formula might give good results provided different coefficients were used in each different gun. Owing to the complex nature of this formula, however, the determination of these coefficients as well as the use of the formula is not a simple matter but is a time consuming operation. No particular advantage appears to be gained in using the complex formula as it has been shown even with the meagre data in Table XI that the simpler expression is accurate enough for all practical purposes.

CONCLUSIONS

8. The Tables based on the old velocity formula in Ordnance Pamphlet 1872 and in Artillery Circular M, have been shown to be inaccurate in each of six sets of temperature-velocity data which have been studied. This inaccuracy is partly explained by the fact that the temperature coefficient has been shown to vary in different cannon and with different ballistic conditions in the same cannon. A simple empirical formula for predicting the effect of temperature variations upon velocity has been presented which gives results accurate enough for all practical purposes, provided temperature data is at hand for the particular gun in question. A similar formula is presented showing the effect of pressure. If no temperature data is available, the best value of the constants to use in these formulas will be those of a cannon of similar interior ballistics; i.e., as regards chamber volume, weights of charge and projectile, velocity, pressure etc. It is probable that each of these interior ballistic factors has a definite quantitative effect upon the temperature coefficients. As far as is known, however, no serious attempt has yet been made to discover a method which will take account of all of these various factors; hence until some such method is discovered which will be applicable to all guns one must rely upon empirical formulas such as presented in this report. A simple method has been given of determining the constants in empirical formulas, and it is recommended that these formulas be adopted at Proving Grounds instead of the existing tables whenever possible.

Part V

MISCELLANEOUS PROBLEMS IN INTERIOR BALLISTICS

The purpose of Part V is to discuss certain minor problems of interior ballistics which have been studied at the Aberdeen Proving Ground. A complete examination of all the velocity firing records at the Proving Ground was undertaken by the Interior Ballistics Division. This examination was made with the object of securing data from which to develop methods for the correction of velocity and pressure measurements for variations from standard conditions, (these methods to be applied to Range Table preparation). The examination was made primarily to determine correction coefficients for variations in *weight of charge, chamber volume, weight of projectile, density of powder, travel of projectile in the bore, temperature of powder, and erosion.* Careful notes were made, however, of all accurate data which could be found relating to other possible causes of variation in velocity and pressure. It was desired to determine particularly *all possible causes* of variation in *velocity,* on account of the dispersion, or inaccuracy, which such variations, unless corrected, might produce in Artillery fire. It is evident that this problem of reduction of dispersion, or what amounts to the same thing, increasing the accuracy of artillery fire, is a problem of the first importance. As has been shown in Part II, dispersion in velocity accounts for a large proportion of the total dispersion in the *ranges* actually obtained. Hence, it is essential for accurate shooting to secure close uniformity in the *velocity* of the projectiles. A mathematical study was first made of the most important factors (above mentioned) causing dispersion in velocity. These factors have already been fully discussed in the preceding parts.

PRIMERS AND IGNITERS

2. A comparison of the velocity produced in the 4.7″ Howitzer using a regular 110 grain primer, with that produced by the same weight of igniter in the form of a 20 grain saluting primer and 90 grains of black powder in the core, showed a value of 906 f.s. in the former case and in the latter case 895 f/s. The maximum variation in each case was 18 f/s. These firings consisted of two groups of six rounds each. As will be noted, the regular 110 grain primer gives the greater velocity, but there was no change in the uniformity.

3. Firings were made at Sandy Hook to determine the most advantageous size of primer in the 3″ Field Gun. The data is given in full in Table XII.

TABLE XII

Date	Primer	Velocity	Maximum Variation	Remarks
11/17/17	40	1670	32	Each group 5 rds.
"	50	1673	26	
"	60	1679	21	
"	70	1682	20	

These experiments indicates that the uniformity is better, the larger the primer. This result is in accordance with other experiments. For example, in a comparison of the 49 grain primer (U. S. Cartridge Co.) with the 110 grain primer (F. A.) in the 3″ Field Gun the results shown in Table XIII were obtained.

TABLE XIII

Primer	Velocity	Maximum Variation	Rounds
49 grain	1700	3.82%	13.
110 "	1672	1.55%	12

It is concluded therefore, that better uniformity is secured with the larger primers.

4. Arrangement of Igniters. Experiments to determine the best position of the igniter in the powder charge indicated that it should all be placed in the rear of the base section. Thus, in one set of firings, the arrangement of the igniter *all in the base* gave a maximum variation of 27 f/s, while with parts of the igniter in the *increment*, the maximum variations were 49 f/s and 63 f/s, respectively, according to the particular arrangement in the increment. Another set of firings, the data for which is given in Table XIV, also showed that the powder should be in the rear section only:

TABLE XIV

	BASE		INCREMENT		
trial	base	core	base	core	Maximum Variation
a	8 oz.	-	-	-	1.32%
b	3	5	-	3	3.15
c	8	-	3	-	3.04
d	11	-	-	-	2.67

It will be seen that trials a and d where the powder was all in the base gave the best results.

EFFECT OF REMOVING THE LIP FROM A ROTATING BAND

5. The removal of the lip from a rotating band would be expected to injure obturation somewhat. This would tend to decrease the velocity owing to greater gas leakage past the band. Furthermore, the removal of the lip usually causes an increased seating which results in a slight increase in chamber volume, this also tending to decrease velocity. On the other hand, the removal of the lip by machining tends materially to reduce the friction in the bore of the gun, and this fact would tend to *increase* velocity owing to the greater acceleration of the projectile by the powder gases. Finally, the smaller firing pressure required to start the projectile would give the powder a slightly less time to burn before the shell starts, with a consequently decreased maximum pressure and velocity. This last effect is generally considered the largest of the three effects of the removal of a lip on velocity. The following sets of firing data (see Table XV) show the actual difference obtained in the 6″ Wheel Mount and the 8″ R. R. Mount.

TABLE XV.

Date	Gun	No. Rds.	Increase due to Machining lip
Sept. 6	6″W.M.	7	18 foot seconds
" 12	"	10	4 " "
" 12	"	10	−8 " "
Oct. 28	"	14	10 " "
		Mean increase..	.... 6 " "
" 30	8″ R.R.	8	−1 " "
" 31	"	10	5 " "
Nov. 5	"	6	−41 " "
" 14	"	9	100 " "
		−Mean increase	.. −7 " "

The data are seen to be exceedingly erratic, but they indicate, if anything, that removal of the lip of the projectile, produces no change in velocity.

EFFECT OF BOAT-TAILING

6. The removal of metal from the rear of the projectile by boat-tailing *reduces the weight* of the projectile, and at the same time *increases the air space in the powder chamber.* The

reduction in weight tends to *increase* the velocity, while the increase in air space tends to *diminish* it. Knowing the exact values of the variations in weight and of chamber volume, however, the net effect of these variations upon the initial velocity may be readily calculated by the following formula- (See Part II.)

$$V = nV\frac{\Delta P}{P} - \beta V\frac{\Delta S}{S}$$

where v = velocity
P = wt. projectile
S = chamber volume
$n \& \beta$ = constants for the gun
ΔP = change of wt. of projectile
ΔS = change of chamber volume.

Furthermore, since the powder gas pressure would be released at the muzzle slightly *sooner* in the case of the boat-tailed projectile than in the "straight" base type, this fact would also tend slightly to diminish the initial velocity. No experimental data as to the exact amount of this reduction at the muzzle are at hand but from the incomplete data available it is believed to be extremely small and probably can be neglected in most work. In predicting the effect of boat-tailing, the above formula will probably give sufficiently accurate results for all practical purposes.

EFFECT OF VARIATION IN ANGLE OF ELEVATION

7. Very little is known about the exact effect of variations in the angle of elevation upon velocity. To carry out an investigation of this effect over a wide range, is a matter of considerable experimental difficulty. Three reasons have been advanced why the velocity should not be constant at different angles of elevation:

(a) Because of a difference in the seating of the projectile particularly in cannon of the larger calibers, due to difficulties in ramming.
(b) Because of a difference in *ignition* because the charges rest in intimate contact with the primer, or the mushroon head, as the case may be, and
(c) Because of a *higher pressure and rate of combustion* of the powder due to the action of gravity on the projectile while in the bore.

In regard to (c) above, it is believed that the effect of the action of gravity on the projectile is negligible in comparison to the pressure on the powder gases. To take an extreme case, in the 14" gun, where the weight of the projectile is 435 lbs., it has been computed that at the maximum elevation of 45°, the increased pressure due to the force of gravity will be only 2 lbs. per square inch. It is seen that this force is extremely small in comparison with the maximum pressure of 40,000 lbs. per square inch, for this gun, (i.e. only .005%) and it is believed therefore that any higher initial pressure or rate of combustion of the powder due to the action of gravity will be negligible in all practical work.

Several rough experiments have been carried out in the 3" and 6" guns to test the effect of elevation upon velocity. Since the results have been contradictory and no definite conclusions whatever could be drawn from them, the data will not be presented at this time.

In view of the reasonable doubt which still exists as to whether the velocity is constant for various angles of elevation, it would seem desirable that this question be thoroughly investigated.

EFFECT OF CONTAINERS

8. It has long been the common practice in artillery firing to use bags of *silk* as containers for the powder charges in separate loading guns. Silk has proved quite satisfactory for this purpose. From time to time containers of cheaper materials have been tried, such as chemically treated cotton, pyralin, etc. No data are at hand regarding the chemically treated *cotton* but the data shown in Table XVI were taken from an investigation made at the Aberdeen Proving Ground of a proposed *pyralin* type of powder container.

TABLE XVI

Date	Cannon	Container	Velocity	Maximum Variation %
6/15/18	155 mm. How.	service bags (silk)	1472 x	1.08
"		pyralin containers	1530	1.96
"	155 mm. Gun	service bags	2348	1.62
		pyralin con.	2464	1.50 (sparks left in gun)
"	8" Howitzer	service bags	1306	.38
		pyralin con.	1335	2.47

x The low velocity of this group was due to the fact that the service bags had been made up for two weeks.

It will be seen from table XVI that in the howitzers the pyralin containers were inferior to the silk on account of poorer uniformity, and they were also inferior when used in the gun on account of sparks being left in the gun. Pyralin containers may be quite useful in trench mortars and other inaccurate cannon, because of their convenience and cheapness, but they are not recommended for use in the regular cannon.

EFFECT OF CRIMPING

9. Variations in the method of crimping of the cartridge case upon the projectile were suspected as being a possible cause of dispersion in velocity. This matter was therefore investigated. The results follow:-

TABLE VI

Gun	Charge		Velocity
75 mm. British	26-5/8 oz.	crimped	1706 f/s.
		not crimped	1709 f/s.
		difference	3 f/s.
75 mm. British	27 oz.	crimped	1735 f/s.
		not crimped	1736 f/s.
		difference	1 f/s.

It is seen that crimping has practically no effect upon velocity. This agrees with the results of experiments carried out with Small Arms .30 caliber cartridges by the Inspection Section of the Ordnance Department. In these tests similar negative results were obtained. Crimping can, therefore, be eliminated from further consideration as an element in causing variation in velocity.

EFFECT OF OBTURATORS IN OLD GUNS

10. In new guns, the use of special *obturators* has been found to have practically no effect, but where the gun is worn, a considerable increase in velocity may result from their use. For example, in the American 75mm. gun, Model 1916, it was found that where the gun had been fired 8000 times, the use of obturators after that time caused an increase of 15-21 f/s in the velocity over that obtained without them. The velocity dispersion was also improved. It was also found that when obturators were used on all 8000 rounds their use caused a greater *erosion* than in a gun fired under similar conditions with no obturators. (From experiments made by Capt. Dickson, at the Aberdeen Proving Grounds).

CONCLUSIONS

11. In this report seven minor factors which were thought to have a possible influence upon muzzle velocity have been discussed. In brief, the following conclusions may be stated:

(a) Effect of igniters upon velocity—distribution of igniter in base gives best uniformity: and an increase in size of primer improves the uniformity.

(b) Effect of machining the lip from rotating band,—no change indicated by the data available.

(c) Effect of boat-tailing,—correction formula given.

(d) Effect of increasing angle of elevation—results contradictory—believed negligible.

(e) Effect of powder container—silk better material than pyralin.

(f) Effect of crimping—none.

(g) Effect of use of obturators in old gun—improves dispersion and gives slightly increased velocity.

FROM A RECENT LETTER—

Also please enter me as a life subscriber to the "Journal of the U. S. Artillery"—the uncertainty of the mails while on foreign service may prevent renewal of a yearly subscription within the time set in your recent notice and I don't want my "Journal" stopped for any such reason—it's the only home tie of an artilleryman interned in the Q. M. Corps.

The JOURNAL wants to be
your "Home Tie"

EDITORIAL REVIEWS

GET TOGETHER

Every year, the boys from one end of the country to the other, prep school boys, high school boys, college boys, get together and furnish their elders with an illuminating example in good citizenship and concerted effort for the common good.

They turn out by hundreds for the serious business of foot ball—which by the way is a wonderful game, typifying vividly many things which all of us, statesmen, professional men, army men, business men, and average citizens, might study with profit to the country and to ourselves. In each school, they turn out voluntarily in bunches to work for places on the team. Under the sweater of each is a budding ambition, the hope of making this or that place on the Varsity team.

For weeks they undergo the gruelling monotony of training, gladly, eagerly, doing their level best to make good. Finally things begin to take shape and, from the bunch of aspirants, a team emerges. For every successful contestant, there are half a dozen disappointed youngsters who must content themselves with the comparative background of the scrubs or who, perhaps, have to retire from the game. Someway they manage to drown their disappointment in their hopes for the team. They know that there can be only one center, one quarter, one captain, two halves, two ends, and so on, and that's all there is to it.

When the team gets down to business, everybody turns to and roots for it. The team has a mission—it must uphold the honor of the school. Nothing but perfect teamwork, in the Varsity, in the scrubs, and on the bleachers, can make a winning team. The season begins. There are plenty of hard knocks, plenty of disappointments, individual and collective. Players pull boneheads and lose their places. The Management sags and has to be bolstered up. Old fellows are called back and do what they can to patch up weak spots, and in one way or another the team pulls through the season. Comes the period of reckoning when everybody, management, teams, rooters, all sit down to figure out some good reason for being proud of the team's showing, some good excuse for each failure. As a rule, when they talk over the season's work, they dwell on their successes—not their failures. They invariably end each discussion with a resolve to do better next season.

Some years ago, the army slipped quietly over into the field of sport and appropriated from the youngsters a word, a fine, virile word, and incorporated it in the military vocabulary. That word was Teamwork. In the operation, they overlooked one thing—in their haste to appropriate the word, they failed to take the spirit along with it. They have cherished that word in the army, have conjured with it, have had great hopes from it, but all to little purpose, because the spirit of the word is the whole essence.

What is that spirit?

Briefly, it is getting together, spiritually as well as physically, getting down to heart-breaking, shoulder-to-shoulder, self-sacrificing effort for the common good, effort in which the individual is glad to lose his identity in the team of which he forms a part.

We had a war. We were not ready for it. Who was to blame for that is beside the question. We were up against it. We had to get down to business, throw together some sort of a fighting force and do the best we could. In throwing together this force everybody who could do so took a hand. Some of those who took part in the operation knew quite a little about the job; some knew a little; some knew nothing whatever, but were willing to learn.

The result? We got together an army of sorts, a team which required a lot of careful nursing, a lot of pushing and pulling and hauling, but which in the end accomplished our purpose—not economically nor in workmanlike fashion, but substantially. We may as well admit that we muddled, but we muddled through, which was as much as anyone had a right to hope for.

The regular army, the national guard, and a good part of the country at large had a hand in the job. What part each played is neither here nor there. Each undoubtedly did his best according to his lights. A great many of each made good, did wonders considering the circumstances. Some of each were rank failures which was not surprising since we humans fail in everything about as often as we succeed and, after all, war is only one kind of business. Statistics would probably show that the percentage of failure throughout was about even.

Now, in reviewing the season's work, do we thank our lucky stars that we got off as easily as we did? Do we congratulate the country and ourselves that we did no worse in the face of our handicaps? Do we decide to let bygones be bygones and resolve to profit in future by our obvious mistakes?

It does not appear that we do.

Congratulations are drowned in the sound of knocking, knocking from all sides, among the members of the team, from among the oldtimers and the newcomers alike, from the bleachers and from the bystanders. Instead of getting together and trying to hearten up things a little with a view to doing better in the future, the team is splitting up into bunches and passing the blame. And the rooters and the bystanders—without knowing much about the game except the spectacular part, they are finding fault with this or that player, criticizing the running of the team in general, pointing out where mistakes were made and how, and by whom and how it should have been done, and so on down through the whole gamut of hostile criticism.

And nobody appears to be giving a thought to next season.

Of course, the fault lies with the players. They bungled because they had never had a chance at team play. They had no chance at team play because we had no team. We had no team because no one took any particular interest in getting up one. And that's the crux of the matter.

We are all grown up men. Let's get together and play the game the way the boys do—but don't let them know it and have the laugh on us.

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"ALL TOGETHER—LET'S GO!"

An effort was made to fight the great war from which we are now emerging with the service divided into three forces—the Regular Army, the National Guard, and the National Army. In this national crisis it became necessary to combine these more or less antagonistic forces into one United Army of the United States in which all worked for the success of the whole. If these forces drift apart, if advantage is not taken of the cohesive spirit that has been developed in the services generally, it will be increasingly difficult as time goes on to develop a really national force in periods of emergency.

By their close association on the battle-fronts of France, the different arms of the regular army have been drawn together in mutual understanding and respect to a degree that had not existed before the war. It is hardly too harsh to say that the traditional attitude between the arms of the service in the old Regular Army was one of thinly veiled suspicion, jealousy and antagonism.

This present foundation for better understanding which the war has left as an incidental legacy puts the army on the threshold of two choices, either we may revert to pre-war disjunction, or we may sustain and strengthen the cohesion developed during the war. Inertia and a negative attitude will allow the service to drift back into the old conditions. On the other hand, a positive decision is necessary if solidarity is to be maintained and increased.

There are several reasons why an imperative necessity exists for cohesion throughout the services. The most important only will be enumerated.

First, there has been much misunderstanding and criticism arising not only from the mistakes of the Regular Army, but as well from the mistakes of the National Guard, the hastily raised levies, the emergency enactments of Congress, and the historic lack of military policy and prevision on the part of successive administrations and the American People. Therefore, a united front should be presented by all arms of the services to repel unjust criticism that may be leveled at any particular branch. At the same time, this solidarity should hold an equal willingness for each arm and the services at large to accept and profit by just criticism.

Secondly, there is in certain quarters a disposition to saddle upon the country a military policy which would perpetuate and increase the evils of our past history in political interference and divided control. This propaganda can not make headway with many of the thinking people of the country, provided the services themselves do not destroy confidence by friction and disagreement of ideas within their own ranks.

Again, without unity of purpose and harmony of doctrine no arm of the service and no one of the forces composing the army can achieve its full measure of efficiency and usefulness. Mutual confidence is as necessary to success in the efforts of the different arms as in the relations of a family or in the transactions of business and banking.

If we agree that we ought to get together, the question then is, how are we going to do it? First of all, the services must realize that a radical overturn of thought and attitude is a human possibility, frequently exemplified. This nation was founded on the conceptions of individualism which in the eighteenth century were cropping up independently in several quarters of Europe, and which dominated the political and economic practices of the unfolding modern world up to a period later than the middle of the nineteenth century. Now on every hand we are confronted with the growing ascendency of collectivism over individualism. A man's house is no longer his castle. Our forefathers would have resented as a tyrannical intrusion upon their liberties the building restrictions, sanitary inspections and ban on backyard pigs and chickens which we accede to nowadays. The fathers of our democracy would have been horrified at the invasion of private property rights involved in the inheritance taxes to which we yield. It took an amendment to the Constitution to render possible the levying of an income tax.

So, in a modern world of overturn and inevitable radicalism, it is, after all, a simple change in viewpoint for the army to cast aside its traditional prejudices and jealousies, its narrow loyalties to the interests of any one arm, in place thereof seizing upon a new earnest devotion to the Army and a spirit which will jump to the support of any branch of the services.

The army must awake, face the new direction, and take this new step. The past must be buried. Bygones must be bygones. The army must get together, stand together, and then hold the positive spirit of accomplishment—"Let's go!"

To do this, elements of friction, inequality and injustice must be eliminated. It is futile to say we will have no friction in future and at the same time to harbor the seeds of friction.

Unity must include *all branches* of the services. No arm may be overlooked or conspired against without surely wrecking the strength of the whole. If there be one branch of the service, even though it be small and an auxiliary arm of limited scope, which yet is denied its just prestige and recognition, and by combination among other arms is subjected to discrimination and repression, such an arm will be a humanly inevitable source of poison. Too generally officers in one branch of the service lack specific acquaintance with the problems and technique of other arms of the service. It is then so easy to jump from ignorance of the other fellow's work to the conclusion that the other fellow's work is not worth while. There is this much to remember—the more earnestly do all arms and corps devote themselves each to the development of their own fields of effort, the more highly specialized will become the technique of each arm of the services, and hence the more unlikely that each will keep touch with the work of the other. Therefore, though it be desirable that every officer should be reasonably familiar with the work of all arms of the service, yet in practice this condition will become increasingly impossible. Nevertheless, in the interest of mutual confidence, it is imperative that every officer, lacking specific knowledge of another's work, should assume that the other's work is as important and worth while as his own.

Again, there will recur in the future, as in the past, through the concurrence of circumstances, opportunities for officers in one service to seize a political or other advantage in which the army as a whole will not share. In the development of the spirit of solidarity which is now foreshadowed, there must be a general acceptance of disdain for the advantage to be attained by any such means Even if there remain individual officers who would not scorn to further their arm at the expense of the army, the public opinion within each arm must spurn the acceptance of the advantage. Every arm of the services to varying extents, has pursued selfish practices in the past. It may not be possible to wipe out all inequalities which the past has created. But every effort to do so must be made, and the record of the future kept clean.

Every arm of the services stands at the threshold of a new opportunity, which simultaneously has confronted the appreciation of each. The reactionaries will curl the cynical lip of doubt and will drag out all the old bogies of distrust and animosity. Of course, with no impulsion but doubt and distrust, neither this nor any other new spirit will go. What is needed is the pouring forth of the same flood of fresh courage and confidence which made our armies in France invincible, the union of all officers whose spirit says—"Can do!"—and—"Let's go!"

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INFANTRY TRAINING IN THE COAST ARTILLERY

Before the war, one of the essential elements of instruction of Coast Artillery troops was a fairly complete régime of Infantry training. As will be well remembered, the schedule included not only close order drill, but extended order, combat training, patrolling, advance and rear guard work, and small arms practice, the whole schedule for each season being topped off with a two weeks' program of service in the field as Infantry.

In those days neither the Coast Artillery nor any one else had realized the tremendous expansion in the demand for the use of heavy artillery in mobile warfare. As we now understand military operations, there is no longer any such thing as siege artillery, and guns of the heaviest types are mounted and classed as mobile weapons. The functions of the Coast Artillery Corps have been greatly enlarged in scope by the responsibility for the handling of the heavier types of ordnance matériel, tractor, caterpillar, and railway. Furthermore, the Coast Artillery is charged with the manning of anti-aircraft artillery and trench mortars, each of which classes of weapons demands a very specialized tactics and technique, even though the demand for their use is in a very limited field.

Now in shaking down to the inevitable routine of peace time effort, the Coast Artillery must occupy this expanded field of responsibility,—a field which includes a wide variation in specialized tactics and technique. In laying out a program to meet these new requirements, we are bound to appraise the relative importance of the different demands upon the Corps, and should assure ourselves that we do not clog our effort by scattering our energies in unprofitable directions.

There is consequently a suggestion of immediate and profound importance for the discussion of the Corps as to the extent to which attention and effort should be devoted to Infantry training.

The JOURNAL has no ready-made answer to the question, but is willing to venture a couple of suggestions in the confident belief that they will constitute bases of principle which nearly every thoughtful officer will accede to, no matter what his further convictions on this subject may be. The first of these suggestions is this: That, no matter whether the Coast Artillery can afford to devote enough time to Infantry training to develop reasonable proficiency as infantrymen, nevertheless the only proper foundation for the development of soldiers in any branch of the service is the basic training of the infantryman. No matter what our demands may be for gunners, mechanics, tractor drivers, telephonists, or radio operators, we must have the confidence that each of these men is not only competent in his particular specialty, but is to be depended upon as a disciplined, trained soldier, with wholesome respect for himself, for his comrades, and for military authority. There is no get-rich-quick method of instilling ingrained habits of dicipline. So far as experience has shown in all the past, there is no substitute for basic Infantry training in the building of dependable soldiers. Therefore, regardless of whether it may be desired to consider Coast Artillery units a potential reserve for any Infantry work or purposes, we do need at least the minimum of Infantry work to maintain the solidarity and dependable discipline of our artillery units.

The second suggestion points in a somewhat different direction, and is in line with the assertion of the *United States Infantry Association* to the effect that the only kind of Infantry worth having is *good Infantry*. This suggestion also includes the corollary that if it takes all of the time of the Infantry to weld its soldiers and officers into *good Infantry*, the Coast Artillery Corps can hardly expect to spend less time and produce a creditable product. But the main business of the Coast Artillery Corps is to produce efficient *artillery* units. This suggestion, then, brings us face to face with the question which ought to be decided, should the Coast Artillery henceforth attempt to carry its Infantry instruction any further than is necessary and desirable to attain a high degree of discipline, precision, and alertness in our organizations. Having regard to all the varied demands upon the Coast Artillery in the way of its own essential assignments, the answer might seem to be unhesitatingly that every attempt at advanced Infantry training should be discarded. However, to balance so hasty a conclusion, thought should be given to two factors in national problems:

The first is the fact that despite the acknowledged necessity for mobile troops to supplement the artillery efforts of Coast Artillery personnel in harbor defense or coast defense operations, the traditional paucity of instantly available troops in this country predicates the possibility that at some time a sudden incursion may occur which will find a portion of our coastline threatened and without a sufficient body of Infantry troops on the ground to repel a hostile landing. In such an event it would be imperative that whatever troops were on the ground,—and these would most likely be Coast Artillerymen,—should jump into the breach and be able to do something effectively to meet the emergency.

The second factor arises from the present and probable future distribution of the military forces. There may never come a time when the maintenance of the domestic order in an internal crisis may not depend upon the potential might of the government in the form of available troops. The very fact that the Government is known to have within reach a sufficient number of trained soldiers to repress violence and disorder, will often in itself prevent the starting of any trouble by the irresponsible. Now it so happens that the only federal troops likely to be maintained within easy reach of many of our large cities are troops of the Coast Artillery Corps. With this unlikely, but none-the-less possible, duty confronting the Coast Artillery, consideration should be given to the training which would make the use of Coast Artillery effective in such a contingency.

The JOURNAL is willing to leave the subject at this point for the discussion of the Corps with the expression of only one further assertion of opinion, and this assertion is that all Coast Artillery units and all Coast Artillery officers and men should be thoroughly trained in the employment of machine guns, for the machine gun is a weapon of opportunity with unmeasured possibilities for usefulness to the Coast Artillery, not only in Infantry work, but in the carrying out of its own particular missions, either in coast defense, air defense, or mobile operations.

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VOCATIONAL TRAINING—FROM ANOTHER ANGLE

The presentation of any subject in the department of Editorial Reviews of the JOURNAL is intended to open up discussion upon matters which impress the editors as being of interest or importance to the Coast Artillery, and never, by any means, are they considered by the editors nor should they be interpreted by the readers as pronouncements—either didactic or official. Any editorial in the JOURNAL will have most surely achieved its mission if it provokes a comeback. Printed below is an able comeback on the screed concerning Vocational Training in the October issue. This letter is published in full by reason of its excellent presentation of another point of view, and please note that it is published with the consent of Major Purdie. On any subject discussed in the JOURNAL, if your experience or conviction suggests a comeback, let us have it, and your wishes will be respected as to whether your views should be presented over your signature or not.

"Mississippi A. and M. College,
Agricultural College, Miss.,
October 24, 1919.

"To the Editor of the JOURNAL:-

"I have read with considerable interest the Editorial Review under the caption of 'Vocational Training' which appeared in the JOURNAL for October, and while my impression may be in error, I gather that the JOURNAL did not seem inclined to believe that vocational training, as proposed for the Army, was anything more than a passing, impractical fad.

"If I may be permitted some observations on this subject, it appears to me that training of this character, aside from its undoubted value to the services concerned, should command the most thoughtful attention of all who are interested in the question of the relationship between the Regular Army and the civil population at large. For the past ten years in civil life and later while holding a commission in the military establishment, I have been particularly interested in observing the attitude of the civilian toward the Army. The aggregate conclusion from the impressions gained during this period of observation leads to the unqualified belief that the Regular Army, the military service, possesses a minimum of friends and a maximum of enemies, varying in their antagonism from amused tolerance to vituperative abuse. The burden of resentment appears to be based upon what is, of course, a short-sighted view,—that both the Army and Navy demand what appear to the individual as huge sums for their maintenance without any seemingly adequate productive return. If the policy of confining itself to the purely military features of the responsibility for the effectiveness of the national defense has created the above impression and gained thereby only the most grudging support for the Army, then that policy must be radically in error and highly subversive of the highest development of the service.

"Under our form of government, the military establishment is directly dependent upon popular support for its appropriations and proper development. Any major policy which does not enlist popular interest in the army is defective; a policy which emphasizes and demands a properly organized system of vocational training coincident with the normal work of the service, must necessarily go far towards gaining this popular interest by reason of its direct appeal to the civil population.

"The Coast Artillery has undoubtedly taken many forward steps along the lines of vocational training in properly instructing its enlisted personnel for its technical activities and I believe that it can be stated very positively that this feature has gone far toward acquiring favor for this branch among those who stop to differentiate between the services. Furthermore, I have heard at least one educator of note speak in highest terms of the character of the Enlisted Specialists' School at Fort Monroe. A similar opportunity lies in the hands of the Reserve Officers' Training Corps if properly supported. If such an educational system serves to fortify the impression of the peace-time usefulness of the Coast Artillery, would not a similar system, properly expanded and wisely directed thruout the Army do more than any single project to place the military establishment on the plane that it deserves in popular estimation? And would not the JOURNAL better serve the cause if it gave its unqualified support in a constructive way to such a project?

"K. S. PURDIE,
Major, C. A., U. S. A."

**NEXT TO LAST CALL
ON THIS YEAR'S
PRIZE ESSAY COMPETITION**

PROFESSIONAL NOTES

The Telemetric System of High Burst Ranging

Prepared By Lieut. Montague Blundon,

Traning Section, Office Chief of Engineers

Editor's Note:—Reprinted by the courtesy of "Professional Memoirs" from the "Professional Memoirs," Corps of Engineers, U. S. Army and Engineer Department at Large, Vol. XI, No. 59, Sept.-Oct. 1919.

Due to the resignation of Lt. Col. C. H. Birdseye from the Coast Artillery and his return to the U. S. Geological Survey, he will be unable to complete his series of three articles on High Burst Ranging, of which two have already appeared in the Journal. The present article covers the same ground as Col. Birdseye's proposed third article, and may be considered by Journal readers to complete the series.

INTRODUCTORY

In the May-June number of this magazine there appeared an article on High Burst Ranging, in which was given a summary of the operations, relative to the subject, in the A. E. F., together with a general description of several of the various methods that were in vogue. Mention was made of the attention devoted to this form of indirect ranging by the Flash Ranging Sections of the Engineers, and although, for various reasons, the Engineers never employed the Telemetric System, it has been generally admitted to be the method of greatest refinement and accuracy.

The Telemetric System, by virtue of its detailed refinements, is lacking in being a satisfactory method, but, so far, no other method has been brought forth which in other ways meets the requirements. Undoubtedly, actual ranging tests will bring out many important points for consideration, but, at the present time, it seems that this system will furnish an excellent basis for the study of the theoretical principles involved in all methods of high burst ranging, whether to be employed by the Engineer Flash Sections or by other observation and ranging units.

Before attempting any detailed explanation of the theory and practice of the Telemetric System of High Burst Ranging, it may be of interest to state briefly its development and mention its organization and employment by the ranging units of the A. E. F.

It seems that when the value of the indirect method of ranging was grasped and appreciated by the Allied Armies—having noted the excellent results obtained by its use on the part of the Germans—there quickly developed several lines of theoretical research, diverging to a rather marked extent in the methods of obtaining actual results.

For the most part, the English seem to have adhered to the False Angle of Site method, while the American Flash Sections* directed their efforts more to Ranging on the True Trajectory. The Tangent Reticule method does not seem to have proven very popular with any of the allied ranging units, although very good results were obtained from it by the French S. R. O. T.† groups, and, too, the American Field Artillery made study of its employment.

The French, however, true to their well merited fame as master artillerists, were by no means satisfied with any system in which there seemed opportunity of eliminating errors of observation and of computation. Their research students therefore devoted their keenest attention to the mathematics involved and finally brought forth the most refined of all methods that has so far appeared, and the one generally admitted to possess the greatest degree of precision—*le systém Télémétrique.*

In developing their ranging operations, the Coast Artillery adopted the Telemetric System and detailed a group of officers to the French Telemetric School to study the theory and practice . When these officers had completed the course they formed the teaching staff for a special Telemetric High Burst Ranging School, for both officers and enlisted men, at the Heavy Artillery School of Angers.

With the development of high burst ranging, on the part of the Flash Sections of the Engineers and by the Coast Artillery, it soon became apparent that some division would have to be made in the assignment, on the part of the Artillery Information Service, of such ranging operations. This resulted in alloting to the Flash Sections the ranging for the lighter field guns, while the Coast Artillery was to furnish its own ranging units for the Heavy Artillery. Such an arrangement naturally necessitated a certain amount of liaison between these ranging units, and with the purpose of facilitating such co-operation two Engineer officers were detailed from the Flash Sections to study the Telemetric System at the School at Angers, and then to join the First Provisional High Burst Ranging Section, attached to the 30th Brigade, R. A. R., with its P. C. at Belleville, just to the north of Verdun.

This section consisted of three independent bases, under the command of Capt. Walter Hall, C. A. C., with a first lieutenant in charge of each base. The observation posts, two to each base, were located on the outlying hills of this renowned sector, and one post, in particular, occupied Fort Douaumont, made so justly famous in the defense of this gateway to Paris.

These posts were installed in small demountable portable houses, over which the common chicken-wire camouflage was spread—giving the false contour effect. A vertical and horizontal type of observing instrument was mounted, in each post, on specially constructed tables, and following out the method of the system, each end of a base was located so that reciprocal sights for orientation might be taken between them.

The section got into position, with a very good determination of its O. P.'s, just about two weeks before the Armistice ,and although three efforts were made to range guns of the R. A. R., no actual results were obtained. In the first two cases the adjustment was attempted for an American battery of 19 G's, but the visibility was exceedingly poor, and, although in the second trial the battery commander had posted his own observers who verified the actual bursting of the shells, no bursts could be seen from the Telemetric Stations.

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* 2nd Battalion 29th Engineers (Flash and Sound Ranging Sections), after the armistice changed to 1st Battalion, 74th Engineers.

† Section de recherche de renseignements par observation terrestre—information service employing terrestial observations.

In the third trial the adjustment was attempted for a battery of 164 mm. French naval guns. In this trial, however, the French S. R. O. T. station reported the fire to be percussion shots—showing conclusively, of course, that the fuses did not function as time bursts. It should be mentioned here that there were two types of fuses available to produce bursts upon the trajectory, but comparatively few batteries were equipped with them. These were the "L. D." fuse, with a maximum time interval of 52 seconds, and the "L. D. A." fuse with a maximum of 70 seconds. Both types were suitable for shells of all sizes, except the 75 mm. field piece and the 14-inch American naval guns which were operating along this section of the front. Besides the lack of fuse equipment by many batteries for which adjustment might, otherwise, have been made by the Telemetric Section, other organizations were lacking in prolongation abaques for the particular type of shell, powder charge, etc., supplied to the batteries. These abaques furnish the data required in this particular method of ranging by high bursts, and further comment will be made concerning their use later on in the theoretical discussion of this article.

During these latter days of the War, it will be recalled, the lines were moving rapidly forward, and a reconnaissance had been made for the purpose of moving the section very much nearer the lines, when all such moves were stopped by the signing of the Armistice.

In treating of the theory and practice employed in the Telemetric System the discussion is given under the following captions: General Outline of System, Instruments, Theory, Operation, Comment.

GENERAL OUTLINE OF SYSTEM

As in all operations pertaining to accurate ranging, the Telemetric System presupposes precise locations (co-ordinates) of observation posts, guns and target, together with coadjusted orientation. The theory is based on the employment of only one base—two observation posts, each post being equipped with a horizontal and vertical type of observing instrument. In practice, however, it is most desirable, for purpose of a check, to employ at least two bases in observing bursts.

Each post is in telephonic connection with a central—where all of the computations, plottings and adjustments are carried out—and which, in turn, is in communication with the batteries; only observers and telephone operators occupying the posts. Owing to the general organization of the sections, their function is more for relatively stabilized than mobile operations; their mission is for the General Reserve of Heavy Artillery (A.L.G.P.), and not for the quickly maneuvering field guns. The operations incident to installing a base are very refined and necessarily consume much time, though the argument is advanced that a section should always be able to complete its orientation and be prepared for ranging within less time than required for the larger guns to get into position. Nevertheless, they can never be considered units as mobile as the Flash Sections.

The method of adjustment is based upon the determination of a fictitious point of burst, clearly in the field of view of the observation instruments. All elements relative to this fictitious point are determined in advance of the adjustment, and its location is computed with the same precision as if the point were an actual visible object; for example, a balloon. The data necessary for the location of this point are the co-ordinates, height above the initial plane, the distance of its horizontal projection from the target, and the gisements* and distances from the observation posts. The battery is furnished with the data enabling it to adjust the firing so as to cause the bursts to take place near this predetermined point —toward which the observation instruments are directed.

The observation instruments being clamped along the line of site toward this fictitious point of burst, remain in this position throughout the adjustment, and the deviations of the actual bursts are read, in centigrades, both horizontally and vertically, in the subscales of the telescopes—from this fictitious index point. Data is thereby obtained for defining the particular trajectory on which the actual bursts have occurred, and with this information at hand the *prolongation of the trajectory* can then be computed, and the *theoretical point of impact* for each burst determined. This, in turn, gives the information sought—the deviations in "rights and lefts, longs and shorts."

This method of high burst ranging may, therefore, be defined as—the observation and determination of the position of a shell-burst, in air, near a predetermined fictitious point on its trajectory; and the computation of the prolongation of this trajectory to its theoretical point of impact, in relationship to the target.

With well trained sections it is considered that the initial data required for an adjustment should be prepared within 30 minutes; and, after the bursts are observed, the results should be submitted to the Battery Commander within 5 minutes. This statement is based on the experiences of both the French and American personnel. It must always be borne in mind, however, that a Telemetric Section should be a highly trained specialized unit, the sole mission of which is merely the adjustment of fire by means of observations on high bursts, and the purpose is decidedly not to use the posts for any other form of observations, as, for instance, in the case of the employment of the Flash Sections, in addition to ranging, for the collection of all information pertaining to the enemy's works and movements.

Relative to the time consumed in obtaining actual results from this particular method of high burst ranging, a quotation is submitted from the French document issued from Reserve General d'Artillerie, 3rd Bureau, under date of June 14, 1918, entitled "Reglage Par Coups Fusants Hauts avec Section Télémétrique"; the translation being as follows:

"It is of great importance to maintain to a high degree:

On one part, the training of the observers;

On the other part, the training of the computers and telephonists.

"During the fire of the 21st of May (1918), the time necessary to convey to the battery the results of a salvo was approximately 15 minutes. On the 24th of May, this time had been reduced to 6 or 7 minutes, due to a more methodical handling of the personnel.

"It may be stated that, with a well-trained personnel, the result of a salvo of 4 shots should be given to the battery in 4 or 5 minutes after the firing of the last round of the salvo.

"It should be noted that the method of fire by salvos is, in all cases, particularly advantageous from the point of view of 'lost time.' The observerstions made upon a burst are immediately transmitted to the central computing station, without resulting in inconvenience for the observation for additional rounds; the operations relative to the prolongation of the trajectories are started at the time of the firing of the salvos."

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* Gisement—the horizontal angle which the line makes with Lambert North-Y-line.

INSTRUMENTS

As mentioned before, each post is equipped with a direction and elevation type of observing instrument. These are very much the same in pattern, except for the graduations on the reticules of the eye-pieces, and the direction instrument has, in addition, a special telescope and a horizontal silver circle for setting off the gisement to the predetermined point of burst. These extras are for more precise means of setting off the gisement—the elevation instrument not requiring the same degree of refinement in orientation.

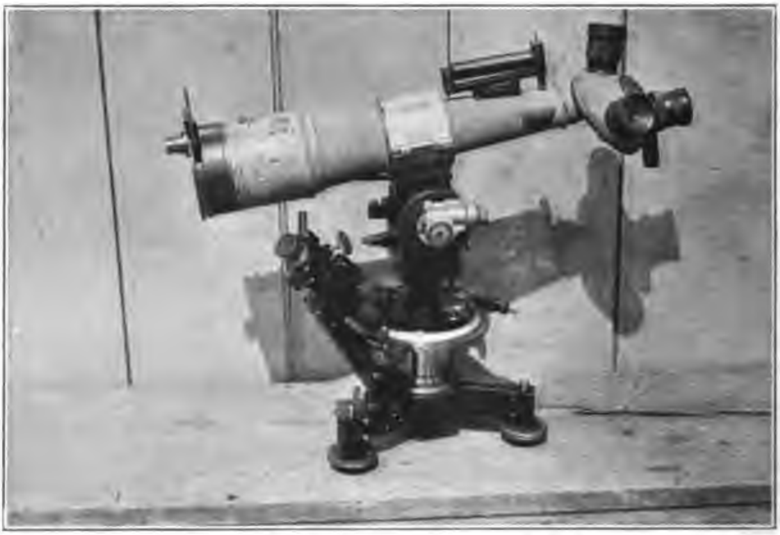


FIG. 1.

The graduations on the horizontal plates of both instruments are in grades, at 2-grade intervals, from 0 to 200, in both directions. Readings counter-clockwise are +, clockwise −. The graduations on the silver circle are of three lengths: full lengths, corresponding to 10 grade divisions; ¾ lengths, to 2 grade divisions; and ½ lengths, to 1 grade divisions.

The telescopes are of the well-known Longue Vue Monoculaire á Prismes style, Type X, fitted with three different power eyepieces, mounted on a "revolver." The night lens contains a device for illuminating the reticule eyepiece. There is also provided a series of colored screens; and an extra attachment is provided for training observers in reading simulated bursts.

There are three brass plates provided for the base leveling screws; one plate being slotted, one with a hole, and the third smooth. These are screwed on the permanent table, in place of the usual tripods, on which the instruments are mounted.

There are trunnion and telescope leveling bubbles on each type of instrument, and, in addition, a prism and mercury bowl are provided for making the instruments truly horizontal. Detail printed instructions accompany each set of instruments, and these explain fully the various adjustments in self-collimation, leveling and orientation.

The two types, direction and elevation, are shown in Figs. 1 and 2.

THEORY

Before treating of the theory involved in the actual ranging operations mention should be made of the form of computations employed in the orientation, in order, especially, that the terms employed in the process of ranging may be made clear.

Counter gisement (represented by the letter V) is the basis of angular measurement in the telemetric system; the angle being measured counter-clockwise from Lambert North. The deviation (less than 100 grades) from the Y-axis is represented by the letter W, and the distance between two points is represented by the letter D.

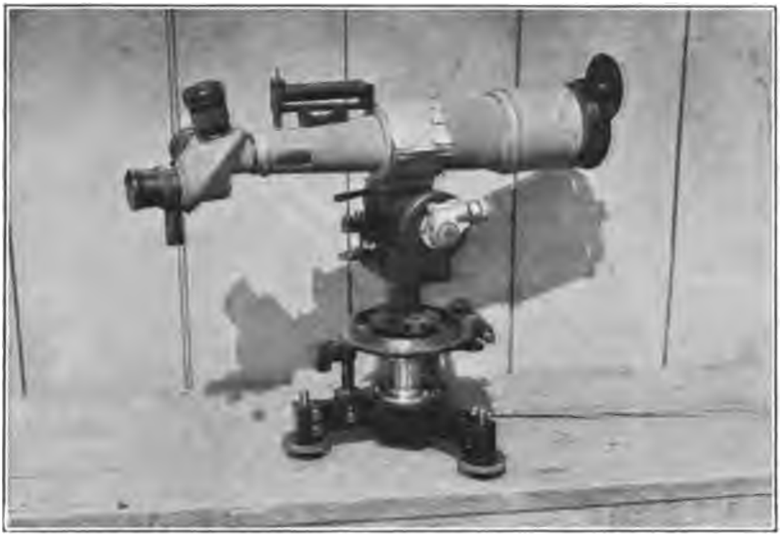


FIG. 2.

A *Telemetric Base* has two observation posts, looking toward the target, the right-hand post is designated T_1, and the left-hand post T_2, the base distance being represented by B, and the co-ordinates by a_1 b_1 and a_2 b_2.

After orientation is completed the angles are referred to a *Directing Line*—perpendicular to the base, toward the target, the gisement of which is represented by V_0.

α and β represent the co-ordinates of the predetermined fictitious *Point of Burst*, Ω, the telemetric elements of which are θ_1 and θ_2—the angles at T_1 and T_2 between the *Directing Line* and the lines of site to Ω; the distances of site are represented by A_1 and A_2, and the gisements by V_1 and V_2.

θ_1 and θ_2 may be either positive or negative, but are always less than 100 grades. If the *Directing Line* should have to be rotated in a positive

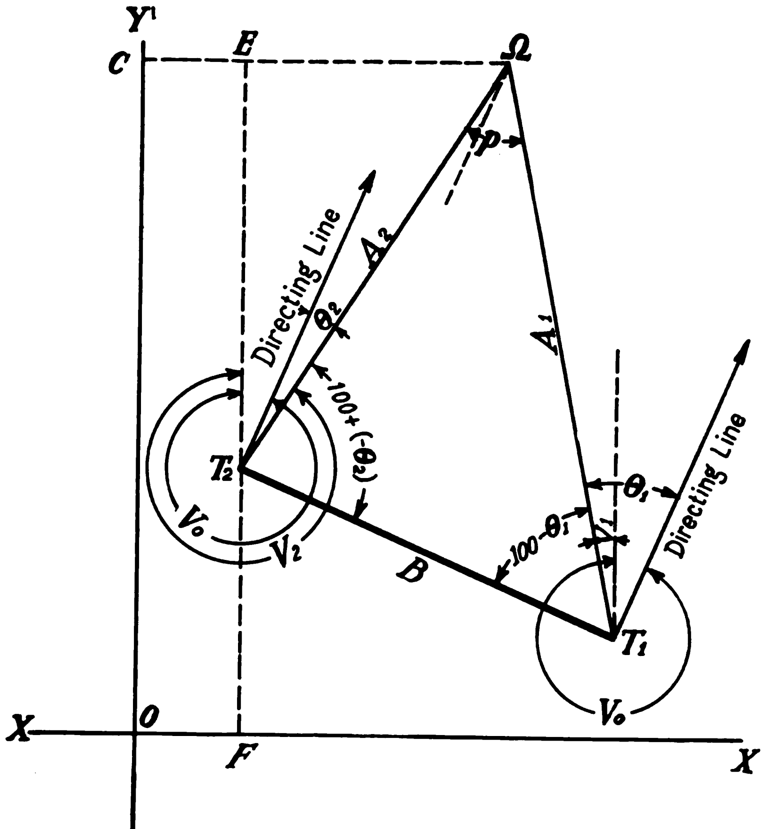


FIG. 3

The following model is used in the computation:

$\alpha =$	$\beta =$	$\alpha =$	$\beta =$
$\alpha_2 =$	$b_2 =$	α_1	b_1
$\alpha - \alpha_2 =$	$\beta - b_2 =$	$\alpha - \alpha_1 =$	$\beta - b_1 =$
Log $(\alpha - \alpha_2) =$		Log $(\alpha - \alpha_1) =$	
colog $(\beta - b_2) =$		colog $(\beta - b_1) =$	
log tan $W_2 =$		log tan $W_1 =$	
$W_2 =$	$V_2 =$	$W_1 =$	$V_1 =$
	$-V_0 =$		$-V_0 =$
	$\theta_2 = \pm$		$\theta_1 = \pm$
			$-\theta_2 = \pm$
			$\rho =$

direction (counter-clockwise) in order to bring it on the line of site from the T station to Ω, the angle θ is positive, and if the reverse operation should be required θ is negative.

p represents the parallax of Ω with respect to T_1 and T_2, and its value is always considered positive. From a reference to the accompanying figure (Fig. 3), the following formulae can be obtained:

$$\theta_1 = (V_1 - V_0)\ ;\ \theta_2 = (V_2 - V_0)\ ;\ p = \theta_1 - \theta_2.$$

The method of reading the horizontal angle to the burst may now be considered. In the reticule forming the subscale, in the focal plane of the telescope, of the direction instrument, is a series of vertical lines graduated in centigrades, right to left, from 0 to 200. The graduation 100 is in the center of the line of collimation of the telescope. It has already been mentioned that the plate of this instrument is graduated in grades, 0 to 200, right and left from the index point, and the problem is one of determining the method of directing the telescope toward the fictitious point of burst, and of reading the deviations of the actual bursts; the procedure is as follows:

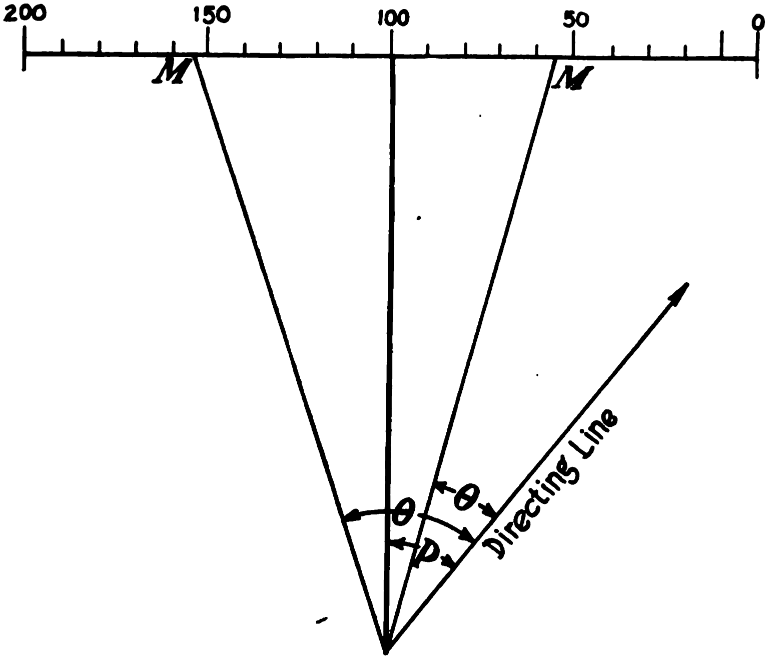


FIG. 4

The telescope is first directed so that when the index point reads 0, its principal axis is along the *Directing Line*. The angle θ is computed in grades and centigrades, but as only the nearest grade P can be set off on the plate, the remainder of the angle, in centigrades, must be read at some division M on the reticule. Fig. 4 explains the principle, and the following equations can, therefore, be formed. These hold true for all values θ and

P, whether positive or negative: $\theta_1 = P_1 + (M_1 - 100)$; $\theta_2 = P_2 + (M_2 - 100)$.

θ_1 and θ_2, having been computed, are known, and the values of P_1 and P_2, being the nearest full grade values corresponding to θ_1 and θ_2, are also known, so that the equations are really solved for M_1 and M_2—the two reticule readings to Ω.

It has been assumed so far, however, that the graduations on the subscale and on the horizontal circle are correct, but this is seldom the case, and the readings should be compensated. The sub-scales in each set of instruments are, by photographic selection, compared until a pair is found as near as possible to be identical. These are selected for the instruments in a single base.

On the sub-scale 200 divisions will, then, really correspond to 200 centigrades plus a correction, represented by $2t$ (with proper sign), and the correction is assumed to apply uniformly to the graduations. The true value of M divisions is, therefore, $M\left(1 + \frac{t}{100}\right)$; where t is the coefficientof compensation for the instrument, and may vary from -2 to $+2$, being expressed by t per cent.

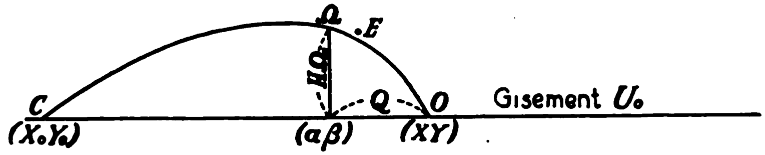


FIG. 5

For the error of calibration of the plates the values of P *net* are given for the different readings of P.

The fictitious point of burst Ω is taken in the vertical plane, through the gun C and the target O, *near* which the actual burst E, used to adjust the fire, will take place. The gisement of the gun-target line is represented by V_0, the co-ordinates of gun being x_0y_0, and of the target xy. The height of Ω, above the initial plane, is represented by $H\Omega$, and the distance of the horizontal projection of Ω from the target is represented by Q. The height and distance are therefore functions of the particular trajectory to be employed in the adjustment, and knowing either of these values it will, later on, be shown that the other may be graphically obtained. Assuming, therefore, that the distance Q is known, the co-ordinates $(\alpha\beta)$ of Ω can either be scaled or computed. The various elements of Ω are shown in Fig. 5.

Having determined the co-ordinates of Ω, the gisements from the two T stations are computed and the observers are given the deflections, from the *Directing Line*, P on the plate and M on the sub-scale, in order to look for the burst. The directions of the telescopes are not altered during the adjustment, but, when necessary, the fuse length is changed so that the bursts may occur in the field of view. The observers read the burst E on the divisions of their sub-scales at M'_1 and M'_2, and the problem becomes one of plotting the horizontal projection of the burst on a chart, where is shown the direction V_0, and the points Ω and O.

The elements for any burst E are θ'_1, θ'_2 and p', and the increment of change is represented by d, so that the following relationships exist—

$$d\theta_1 = \theta'_1 - \theta_1;\ d\theta_2 = \theta'_2 - \theta_2;\ dp = p' - p;\ p' = \theta'_1 - \theta'_2.$$

Also, since during the adjustment P_1 and P_2 remain constant, the following are derived: $-d\theta_1 = M'_1 - M_1$; $d\theta_2 = M'_2 - M_2$; $dp = d\theta_1 - d\theta_2$.

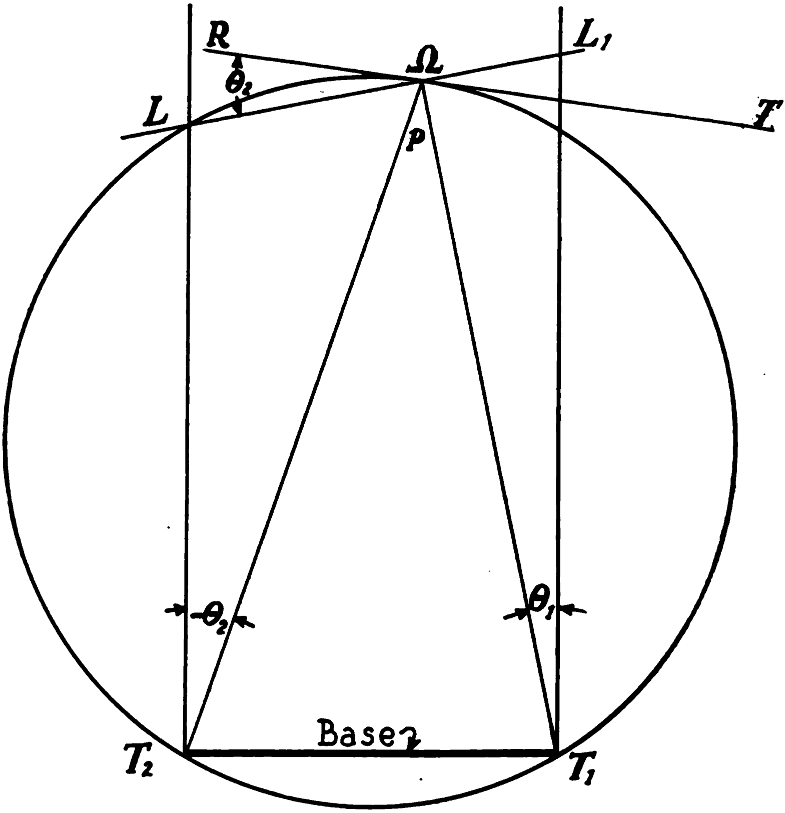


FIG. 6

In Fig. 6 a circle is described through the posts T_1, T_2, and the fictitious point of adjustment Ω. The Directing Line from T_2 intersects the circle at L, and a line LL_1, is drawn through L and Ω. The angle T_1T_2L is, by construction a right angle, and the arc $T_1\Omega L$ is a semi-circumference; and, therefore, the angle $T_1\Omega L$ is a right angle. If, at Ω, the line LL_1 is rotated through an angle equal to θ_2, its new position, RΩT, will be tangent to the circumference at Ω; for the angle θ_2 is measured by ½ arc at LΩ, and in the rotation the whole of this arc has been passed over.

All points along the circumference have the same parallax p, but for a limited extent around Ω we may consider with very little error, that the tangent at this point is identical with the circumference, and that the locus of points of equal parallax will be the tangent.

The line $T_1\Omega$ is the locus of all points with direction θ_1 from T_1; directions are considered positive from T_1 towards Ω; and, on $L\Omega$, positive directions are considered from left to right—for both cases opposite directions are considered negative.

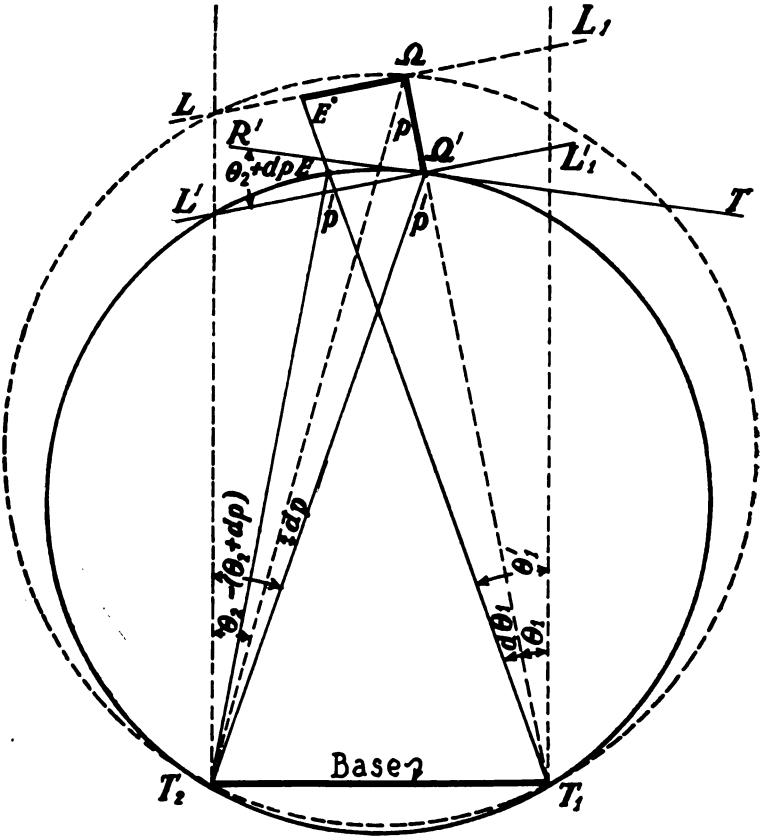


FIG. 7

In Fig. 7, E is the actual burst, and L' the point where the *Directing Line* from T_2 intersects the circle passing through the posts T_1, T_2 and E; Ω' is the intersection of this circle with the line of site from T_1 to Ω. In the same manner, as at Ω, the line $L'\Omega'$ is rotated about the point Ω', through an angle θ_2+dp, to the position $R'\Omega'T'$, tangent to the circle at Ω'. But dp is small, never over 1^G, and $\theta_2 \pm dp$ is practically equal to θ_2, and the tangent at Ω' is for all practical purposes parallel to the tangent at Ω, and the former may be considered the locus of all points of parallax p'.

In the triangle E′ΩT, tan $d\theta_1 = \frac{E'\Omega}{T_1\Omega}$: but $T_1\Omega$ is the distance to the fictitious point of burst, represented by A_1, and since the tangents and sines of small angles are almost equal, the substitution $E'\Omega = A_1 \sin d\theta_1$ can, with little error, be made. Also, since the sines of small angles are very nearly proportional to the angles themselves, $\sin d\theta_1$ can be written $\sin 1' d\theta_1$ (sine 1 centrigade multiplied by $d\theta_1$), and the relationship is, $E'\Omega = A_1 \sin 1' d\theta_1$. The value $A_1 \sin 1'$ is constant for any one shoot, and is called the *lateral sensitiveness* of Ω with respect to the station T_1, or the lateral displacement from Ω for a variation of 1 centigrade in the value of θ_1. This constant is represented by σ_1, and in a similar way $\sigma_2 = A_2 \sin 1'$; and the above expression is therefore written $E'\Omega = \sigma_1 d\theta_1$.

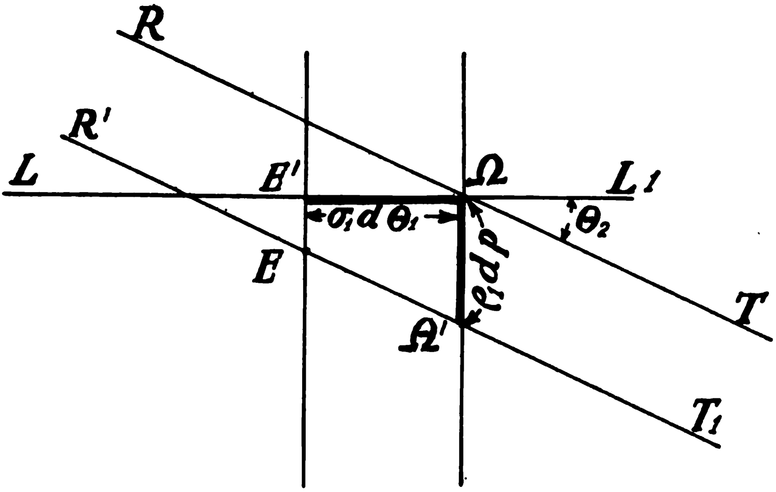


FIG. 8

In the triangle $T_2\Omega\Omega'$, the following proportion is found: $\frac{\Omega\Omega^1}{T_2\Omega_1} = \frac{\sin dp}{\sin p}$; or $\Omega\Omega' = \frac{T_2\Omega' \sin dp}{\sin p}$; but $T_2\Omega'$ is practically equal to A_2, and $\sin dp$ may be written $\sin 1^1 dp$; therefore $\Omega\Omega' = \frac{\sigma_2}{\sin p} dp$. The value $\frac{\sigma_2}{\sin p}$ is, also, a constant for any one shoot and it may be represented by ρ_1, which is called the *longitudinal sensitiveness* of Ω with respect to the station T_1, or the *longitudinal displacement* of Ω, relative to the line of site from T_1, for a variation of one centigrade in parallax. In a similar way $\rho_2 = \frac{\sigma_1}{\sin p}$. The expression therefore becomes $\Omega\Omega' = \rho_1 dp$.

In the immediate vicinity of Ω the lines of site for T_1 to the points of burst may be considered parallel, and are called *parallels of direction*; while the tangents, also considered parallel, are called *parallels of parallax*.

In Figures 6 and 7, it will be noted that the relative displacements of E from Ω are very much greater than would be the case under actual ranging conditions, the deviations having been exaggerated in order to present the relationships. The statement in the above paragraph may, with respect to lines in the immediate vicinity of Ω, be shown practically true to actual conditions by Fig. 8.

To locate any burst E, therefore, from the predetermined fictitious point of burst Ω, a chart is prepared, verticals are drawn spaced according to the value of σ_1, and diagonal lines, inclined from the horizontal by the angle θ_2, spaced according to the value of ρ_1. The expressions $\sigma_1 d\theta_1$ and $\rho_1 dp$ may now be further examined:

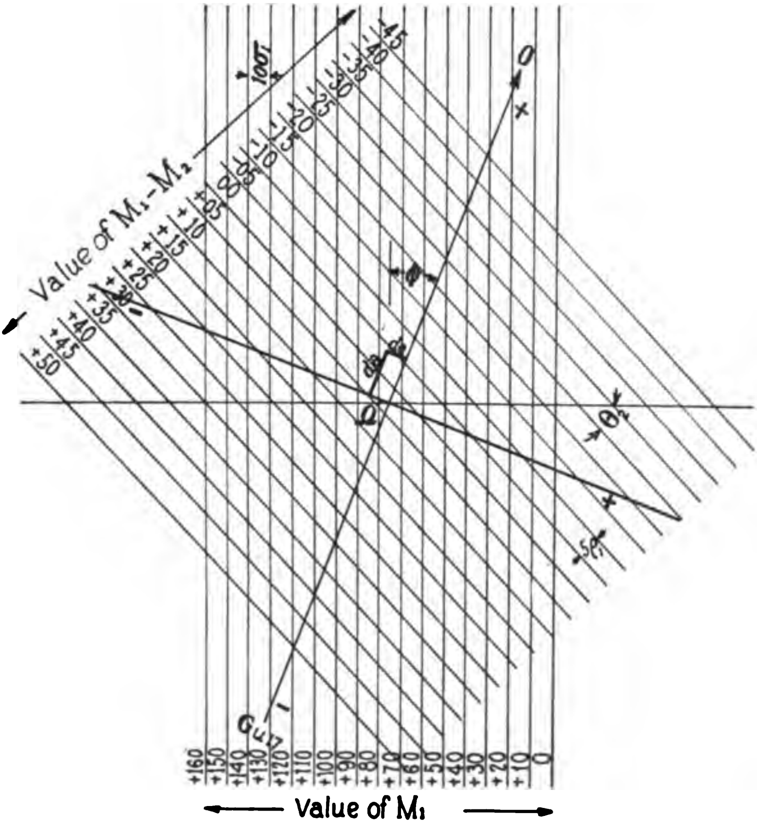


FIG. 9

σ_1 and ρ_1 are constants and their values are determined by graphical scales. As stated above $d\theta_1 = \theta'_1 - \theta_1 = M'_1 - M_1$, or the *difference* between the subscale readings from T_1 station, for Ω and for any burst E. Also $dp = d\theta_1 - d\theta_2 = (M'_1 - M_1) - (M'_2 - M_2)$; or, the *difference* in the subscale, readings to any burst, between T_1 and T_2 stations. The expression may, however, be written $dp = (M'_1 - M'_2) - (M_1 - M_2)$; (Ω is, therefore, plotted by $d\theta_1 = M_1$, and $dp = (M_1 - M_2)$.

In the example given at the end of this article $M_1=75$, $M_2=73$, and $M_1-M_2=+2$; $\sigma_1=0.878$, and $\rho_1=2.917$; $\theta_2=53.^G-26.6'$. The graphic chart is prepared to a scale (1 : 2000, or 1 : 5000) laying off verticals to a horizontal line, spaced 10 σ_1's and lines inclined by the angle θ_2, spaced ρ_1's. The gun target line is drawn through Ω inclined to the vertical $T_1\,\Omega$ line by the angle $\varphi_1=U_0-V_1=370.^G-10'-394.^G-21'=24.^G11$. Fig. 9 shows the construction of this graphic chart. The first shot in the example, $M'_1=76$, $M'_2=80$, $M'_1-M'_2=-4$, is plotted and the deviations, *da* and *de*, are found to be +18 and −7.

So far, only the horizontal projections of the burts have been considered, and it is necessary to determine the heights of bursts in order to prolong the trajectories to the points of impact.

The correction for curvature is expressed by the formula, $S=\frac{D^2}{2R}$, which is always a positive quantity; D being the horizontal distance, and R the radius of the earth, or $S=0.008\ D^2$. The correction for refraction (N) is given by the formula $N=\frac{D}{R}\,m$; where *m* is the coefficient of refraction, taken as 0.089. The combined correction for curvature and refraction is, then, $S+N=.066\ D^2$.

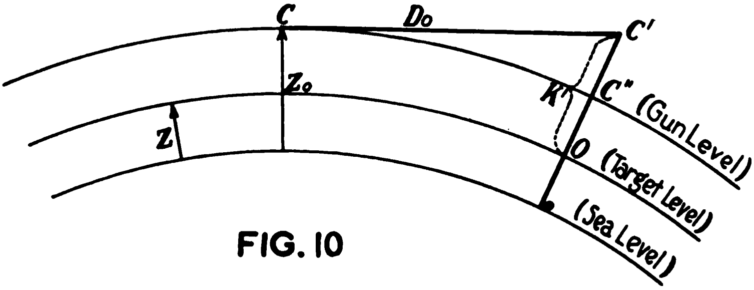


FIG. 10

The following symbols are used to denote the elevations of the principal points:

Z_0 = Elevation of Gun;
Z = Elevation of Target;
C_1 = Elevation of Station T_1;
C_2 = Elevation of Station T_2;
K' = Difference in Elevation between Gun and Target;
J_1 = Difference in Elevation between Gun and T_1;
J_2 = Difference in Elevation between Gun and T_2.

Fig. 10 shows these relationships relative to gun and target, and $K'=Z-Z_0-0.08\ D_0^2$

Fig. 11 shows the relationships of the horizontal plane through the T_1 station, gun and target, and the following formula is obtained,

$$J_1=K'+(C_1+0.066A_1^2-Z).$$

And, in a similar way,

$$J_2=K'+(C_2+0.066\ A_2^2-Z).$$

H′ represents the height of burst above the horizontal plane of the gun and (Fig. 11) $H' = J_1 + E'E$; but E′E is the actual height of burst above the horizontal plane of sight corrected for curvature and refraction, or the value of the angle *i*.

In order that the elevation instrument may be pointed so that the line of collimation to Ω may pass through the 100-mark of the subscale the horizontal line of site will be at a distance $-h$, below the 0-mark. In Fig. 11, $E'E = A_1 \sin i$, but $\sin i$ may be written $\sin 1' \ (m_1 - h_1)$; therefore $E'E = A_1 \sin 1' \ (m_1 - h_1)$. But, as already mentioned, $A_1 \sin 1' = \sigma_1$; therefore $E'E = \sigma_1 \ (m_1 - h_1)$ and substituting in the above equation, we have:

From Station T_1 $H' = J_1 + \sigma_1 \ (m_1 - h_1)$
From Station T_2 $H' = J_2 + \sigma_2 \ (m_2 - h_2)$.

Under any given conditions of fire H′ and *m* are the only variables, and the equation is therefore that of a straight line. A chart is prepared on which this line is constructed, from rectangular axes, representing values of H′. The values of *m* are plotted as abscissae (1 mm. = 1 centigrade) and values of H′ (1 mm. = 2 meters) as ordinates. The slope of this line is σ, and is found by laying off 100 m as abscissa, and 100 σ as ordinate. The line from this point to the origin will then be parallel to the line representing values of H′. The elevation angle to Ω being known, *h* can be assumed equal to *m*, then, $H' = J_1$, and this value of *h* can be laid off as abscissa, and the value of J, as ordinate, and the true line will pass through this point, and will be parallel to the line through the origin, with slope σ. The reading to Ω corresponds to $m = 100$ on the vertical subscale, and the height of Ω (H′Ω) can be read as an ordinate corresponding to this abscissa.

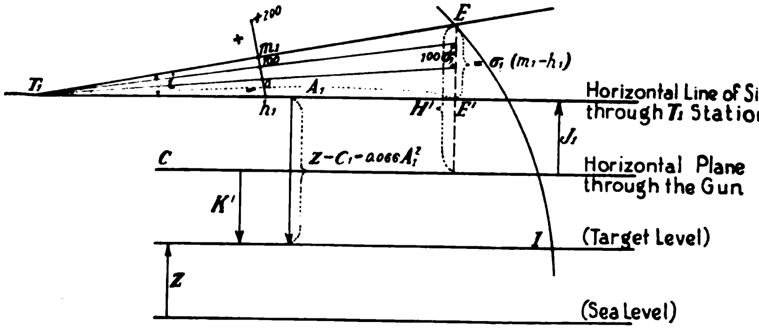


FIG. 11

A similar curve should be constructed for T_2 (on the same chart), and a slightly different value for H′ will be obtained, but the larger value should be adopted. For an approximate value, however, the following empirical formula may be used—

$$H'\Omega = 1.03 \, \sigma_1 \, (100 - h_1) + C_1 - Z_0.$$

Fig. 12 indicates the method of constructing the line for values of H′. The chart is used in conjunction with an abaque (Plate I) which is constructed on the following principle:

The quadrant angle of departure (φ) and the angle of fall (ω) being functions of the range, these elements are plotted for curves representing the prolongation of trajectories. Ranges are laid off as abscissae (1 : 20,000) and values of φ and ω are used as ordinates (1 mm. = 6 minutes). As the angle of fall is always greater than the quadrant angle of departure, for the same range, the curve representing angles of fall is constructed above the quadrant angle of departure curve. Two additional curves for angles of fall are plotted; the upper one corrected for a head wind component of 10 meters per second, and the lower one for the same wind component from the rear. Other wind component values are interpolated.

On the same abaque, with the same axes, are plotted values of angles of fall as ordinates ,and abscissae corresponding to distances of the horizontal prolongations of trajectories, for heights of bursts for even 50 meters.

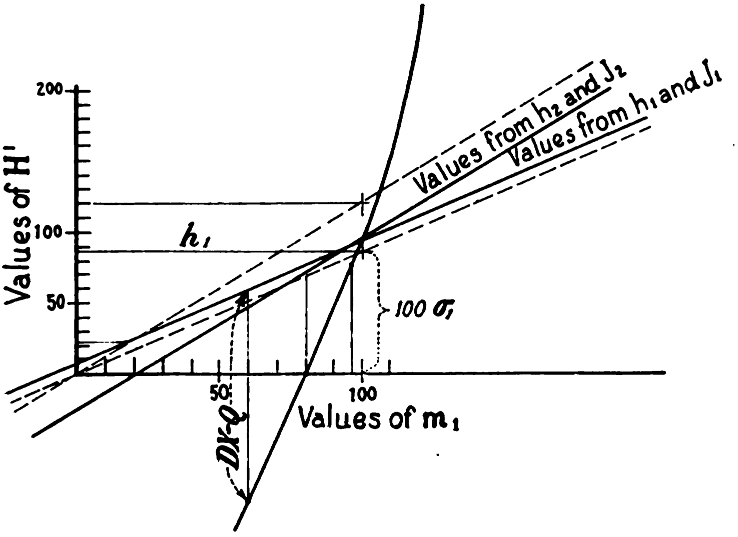


FIG. 12

The lower part of the abaque shows the *lateral* displacement for the prolongations of trajectories. The abscissae are ranges (1 : 20,000) and the ordinates are lateral deviations in meters (1 : 5,000) to the left above the x-axis, and to the right below.

If Fig. 13, E represents the point of actual bursts, and H′ its height above the initial plane, I the theoretical point of impact, and K′ the height below (or above) the point of fall, A′. dx and $d'x$ represent, respectively, the prolongations for height H′ and K′. Then, for the algebraic sum, $DX = dx - d'x$, and $Q = dx\Omega - d'x$; $DX - Q$ is, therefore, the difference between the prolongations for the point E and for the point Ω and it is the distance required, being determined from the prolongation abaque. Abaques are furnished for each caliber of gun, type of shell and fuse, powder charge, etc., and they are employed in the following manner:

Assume the quadrant angle of departure (φ) to be 25°, a head wind of 10 meters per second, and a height of burst for Ω to be 250 meters, with the target 50 meters below the plane of the gun.

Enter the abaque with $\varphi = 25°$, and follow horizontally to the curve of "Angles of Elevation"; then follow vertically to the curve of "Angles of Fall," corrected for head wind of 10 meters per second, then horizontally to the curve of "Height of Burst" of 250 meters—this latter point being the horizontal projection of Ω. To find the horizontal projection of the prolongation of the trajectory for the burst this line is continued to the left to the curve of "Height of Burst" for the height of target, $K' = -50$, to the point $0'$. The distance $\Omega'A$ will then represent the increment $dx\,\Omega$, and the line $A'O'$ represents the prolongation $d'x$, while the line $\Omega'0'$ represents the distance Q. So much is prepared in advance for the shoot.

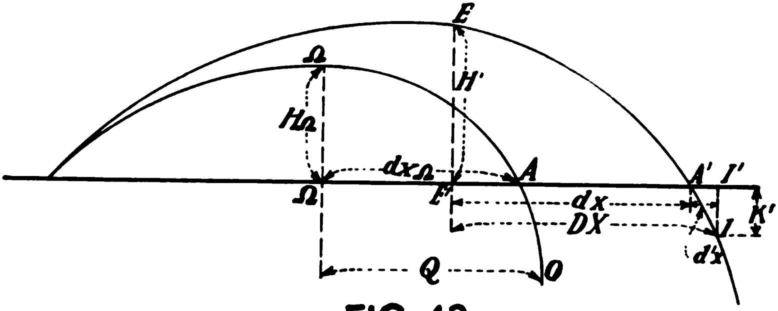


FIG. 13

If the height of an actual burst is found, for instance, to be 200 meters, the point E' will represent its horizontal projection, and the line E'O' will represent the horizontal projection for the prolongation of the trajectory for this burst, equal to DX. The distance desired, however, is the *difference* betweeen the prolongations for Ω and for any burst, or $\Omega'E' = DX - Q$.

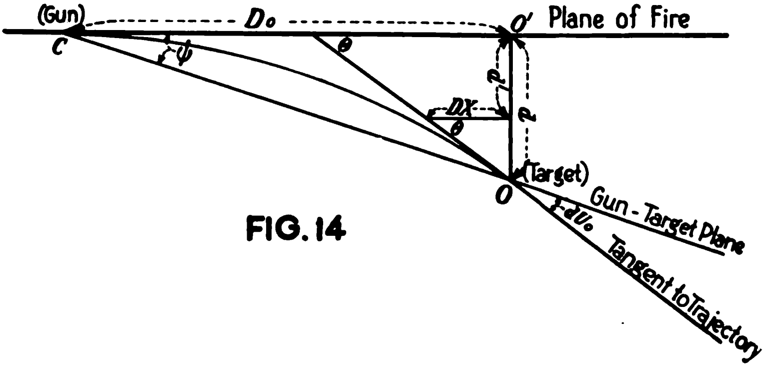
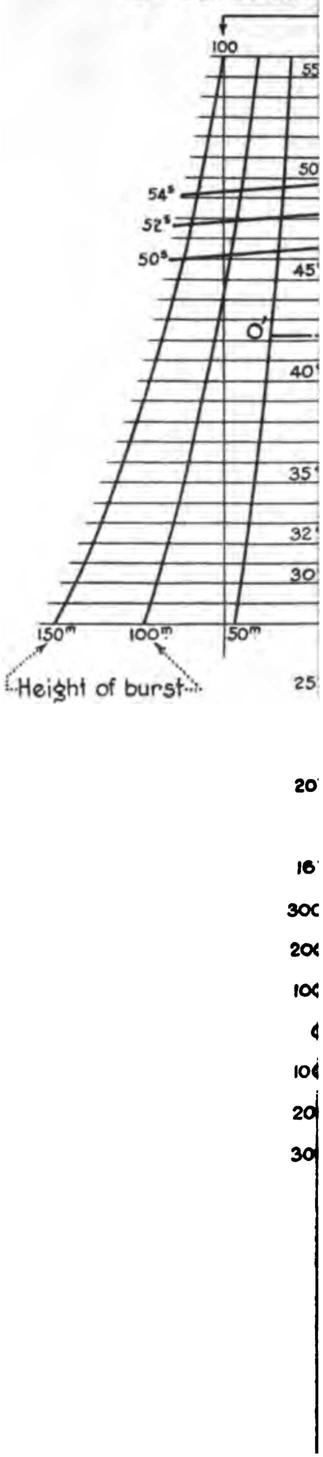


FIG. 14

On the graphic representation of the equation $H' = J_1 + \sigma_1 (m_1 - h_1)$, for each value of m_1 there is a corresponding value H', and from the abaque there is obtained a corresponding value of $DX - Q$, for any particular height of burst. By assuming heights of burst, differing by 50 meters, various values for $DX - Q$ will therefore be obtained, and these may be plotted (Fig. 12) from the diagonal line, from points representing the corresponding values of H'. The result will be a curve which will indicate the value of $DX - Q$ for any reading of m_1.

ABAQUE FOR TE

16cm Gun Model 9



There still remains to be considered the lateral deviation, caused by wind and drift, acting on the trajectory between the observed point of burst and the theoretical point of impact. These values, for drift and various wind components, can either be determined and put in the form of a reference table, or else they may be determined directly from the abaque. In the latter case, the procedure is as follows:

In the example above, for a quadrant angle of departure of 25°, and wind component of 10 meters per second from the right, follow vertically downward, from the point of intersection on the "Angles of Elevation" curve to the curves for Drift and Wind. The line $0'0''$ will then represent the lateral deviation to the left due to drift, and the line $0'0'''$, the deviation to the left due to wind. The sum of these two will then be the total lateral deviation at the target. A portion of this deviation has, however, already been obtained in the determination of the position of E with respect to Ω (*da* and *de*), so that only the amount of deviation between the point of burst and the point of impact is required, or, in other words, a certain function of DX. If dU_0 represents the angle between the gun target line and the tangent to the trajectory at the point of impact, then DX sin dU_0 will express the amount of deviation to be considered. This quantity can be written DX sin $1'dU_0$, or $DX\left(\frac{\pi}{20{,}000}\right)dU_0 = DX.0002\,dU_0$. It remains to determine the value of dU_0, and from Fig. 14 its relative value will be noted.

In the immediate vicinity of the target the trajectory and its tangent may be considered identical, and the increment DX may be taken parallel to the plane of fire. Then $dU_0 = \theta - \varphi$; and tan $\theta = \frac{d-d'}{DX}$; and tan $\varphi = \frac{d}{D_0}$ Or, since the tangents of small angles are very nearly equal to the values of the angles $-dU_0 = \frac{d-d'}{dx} - \frac{d}{D_0,}$ which is, in turn, obtained from the abaque. The lateral deviation will then be expressed by $DX\left(\frac{d-d'}{dX} - \frac{d}{D_0}\right) + DX$ $(.0002)\ dU_0$.

In summary, it might be pointed out that an adjustment requires two distinct divisions in the method of operation. First, the deviations (*da* and *de*) of the actual bursts from the point of fictitious burst are obtained; and, second, the height of the actual burst is obtained, qnd this height is used to determine the prolongation of the trajectory in relationship to the target for the final deviations. The total horizontal deviation is expressed by E, and the total lateral deviation by *e*. By a combination therefore of the two sets of deviations the following is the result—

$$E = da + (Dx - Q)$$

$$e = de - DX\left(\frac{\pi}{20{,}000}\right)\ dU_0$$

From the above it will be noted that *da* and *de* are obtained from the graphic chart, Fig. 9. Q is obtained from the abaque, Plate I; and so, also, dU_0. $(DX - Q)$ is scaled, from the diagonal line to the curve, in Fig. 12.

OPERATION

The method of adjustment is carried out in very precise manner, each step in the operation being definitely defined, so that the procedure may almost be said "to be performed by the numbers." The French pamphlets prescribe that the following data shall be transmitted by the Battery Commander to the Telemetric Section:

(1) The time of opening fire;
(2) The nature of the adjustment required;
(3) The caliber and model of the gun, type of shell, powder charge and fuse;
(4) The co-ordinates and altitude of the battery and target;
(5) The range and gisement from battery to target;
(6) Any miscellaneous information which will assist in the adjustment.

This information is all noted on special printed forms, prepared for the purpose, and as soon as possible the Battery Commander is informed of the height ($H'\Omega$) at which it is desired the bursts shall occur, and the range to the point of adjustment. This enables the Battery Commander to compute the time of flight to Ω, and from special graphs he obtains the proper number for fuse setting.

The Telemetric Section then proceeds with the preparation for the initial data for the adjustment, a plotter and computer working in conjunction at adjacent tables, and the following is the prescribed order of procedure:

PLOTTER	COMPUTER
Plots battery and target on plotting board; checks value of U_0, and determines, by scale, value of $0.08\ D_0^2$	Fills in information sheet, constructs horizontal line on prolongation abaque for proper angle of fall, in preparation for determination of value DX
Plots Ω, approximately, and scales Q, σ_1, σ_2, $0.006A_1^2$ and $0.006A_2^2$, and measures by protrator θ_1, θ_2, and p.	Determines values $dU_0 \left(\frac{\pi}{20{,}000}\right)$ either from tables or from abaque.
Plots line for value of H′, and determines value of $H'\Omega$	
Plots (DX—Q) curve from values submitted by Computer, and submits chart to Computer.	Determines value of Q from approximate value of $H'\Omega$ submitted by Plotter, and checks approximate value.

It will be seen therefore that the system requires plotters and computers quite familiar with the elementary principles of trigonometry, but that each step in the calculations is checked by an independed method. Printed forms are employed for the calculations, and on the following sheet an example has been worked out.

COMPUTATION OF TELEMETRIC ELEMENTS.

Section ....

Base ....

Date................................. **Target:**

Time.................................

Battery ....

$0.08_0^2\ D = +\ 1.78$	$C_2 = +341.$	$C_1 = +358.$
$Z_0^2 = +337.00$	$0.066A_2^2 = +\ 3.79$	$0.066A^2_1 = +\ 2.05$
$-(Z_0+0.08D_0^2) = -338.78$	$C_2+0.066A_2^2 = +344.79$	$C_1+0.066A^2_1 = +360.05$
$Z = +367.00$	$-(Z_0+0.08D^2_0) = -338.78$	$-(Z_0+0.08D^2_0) = -338.78$
$K' = +\ 28.22$	$J_2 = +\ 6.01$	$J_1 = +\ 21.27$

$H\Omega = 118.$ $Q = 250$

$x = +45687.$	$y = +34275.$		
$\alpha^{-x} = -\ 120.0$	$\beta^{-y} = -\ 236.3$	$\alpha = +45567.0$	$\beta = +34038.7$
$\alpha = +45567.0$	$\beta = +34038.7$	$-a_1 = +45060.0$	$-b_2 = +28480.0$
$-A_2 = +41935.0$	$-b_2 = +27385.$		
$\alpha^{-A_2} = +\ 3632.0$	$\beta^{-b_2} = +\ 6653.7$	$\alpha^{-a_1} =\ 507.0$	$\beta^{-b_2} =\ 5558.7$

$\log\ (\alpha^{-A_2}) = 3.50015$	$U_0 = 370.10$	$U_0 = 370.10$	$\log\ (\alpha^{-a_1}) = 2.70501$
$\log\ (\beta - b_2) = 3.82306$	$-V_2 = 363.19$	$-V_1 = 394.21$	$\log\ (\beta^{-b_1}) = 3.74498$
$\log\ \tan\ W_2 = 9.73709$	$\Phi_1 = +\ 1.91$	$\Phi_1 = -\ 24.11$	$\log\ \tan\ W_1 = 8.96003$
$W_2 = 31.81.0\ V_2 = 368.19.0$			$W_1 = 5.79.0\ V_1 = 394.21.0$
$-V_0 = 21.45.6$	$P_2 = -\ 53$	$P_1 = -27$	$-V_0 = 21.45.6$
$\theta_2 = 53.26'.6$		$\theta_1 = -27.24.6$	$\theta_1 = -27.24'.6$
$-P_2(\text{net}) = 53.00$		$\theta_2 - 53.26.6$	$-P_1\ (\text{net}) =\ 27$
$(M_2-100)\ (\text{net}) = -0.26'.6$		$p = 26.02$	$(M_1-100)\ (\text{net}) = -24'.6$
$-t_2$per cent =			$-t_1$ per cent =
$M_2-100 = -27'.$			$(M_1-100) = -25'.$
$+100.$			$+100$
$M_2 =\ 73'.$			$M_1 =\ 75'.$
			$-M_2 =\ 73'.$
			$M_1 - M_2 =\ 2.$

(The printed computation sheet is in the following form.)

Date .... Battery .... Section No. ....
Time .... Target .... Base No. ....

No. of rounds.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M'_1	76	83	89	40	87	91	110	104	72	85	93	110	92	105	78
M'_2	80	76	82	60	76	61	82	92	85	68	97	72	87	95	72
$M'_1-M'_2$	−4	+7	+7	−20	+11	+30	+28	+12	−13	+17	−4	+38	+5	+10	+6
m_1	80	110	115	60	96	102	106	99	120	115	103	94	106	122	98
m_2															
da	+18	−10	−7	+142	−17	−66	−44	−10	+43	−36	+29	−76	+3	−6	−7
DX − Q	−70	+45	+68	−138	−15	+10	+27	−1	+88	+68	+18	−20	+27	100	−8
E	−52	+35	+61	−96	−32	−56	−17	−11	131	+32	+47	−96	−30	+94	−15
DX	195	310	328	127	250	275	292	264	353	333	283	215	292	365	257
$DX\left(\frac{\pi}{20{,}000}\right)dU_0$	3.3	5.3	5.6	2.2	4.2	4.7	5.0	4.5	6.0	5.7	4.8	4.2	5.0	6.2	4.4
de	−7	−4	−10	+17	−5	+11	−12	−24	−16	+5	−29	−3	−18	−25	0
$-DX\left(\frac{\pi}{20{,}000}\right)dU_0$	−3.3	−5.3	−5.6	−2.2	−4.2	−4.7	−5.0	−4.5	−6.0	−5.7	−4.8	−4.2	−5.0	−6.2	−4.4
e	−10.3	−9.3	−15.6	+14.8	−9.2	+6.3	−17.0	−28.5	−22.0	−0.7	−33.8	−7.2	−23.0	−31.2	−4.4

DATA SHEET.

Adjustment No.._______________

Date.____________________________..

Determined by Plotter			Determined by Computer		
D_0	4765	Check battery record	$\left(\frac{\pi}{20{,}000}\right)dU_0$	.017	$dU_0=85$ $\frac{\pi}{20{,}000}=\frac{.0002}{.017}$
$0.08\ D_0^2$	1.78				
U_0	370.10	"	K′	+28.22	
	369.8				
$0.066A_1^2$	2.05		J_1	21.27	
$0.066A_2^2$	3.79		J_2	6.01	
A_1			h_1	17	Submit to Observer.
A_2			h_2	26	Submit to Observer.
Q	250		Q	265	Check value by Plotter.
σ_1	0.878		α	45567.0	
σ_2	1.195		β	34038.7	
θ_1	—26.9		θ_1	—27.246	Check value by Plotter.
θ_2	—53.0		θ_2	—53.266	Check value by Plotter.
p	26.1		p	26.02	Check value by Plotter.
$H'\Omega$	94.44		P_1	—53	Submit to Observer.
ρ_1	2.917		P_2	—27	Submit to Observer.
			M_1	75	Submit to Observer.
			M_2	73	
			$M_1—M_2$	+2	
			Φ_1	—21.11	
			Φ_2	+1.91	

The foregoing, it will be noted, all concerns the initial data, required in advance of observations on actual bursts. It embraces the determinations of all elements required by the observers, in order to direct their instruments to the fictitious point of burst, together with the preparation of the necessary charts on which to plot the angular deviations of bursts, and, finally, to determine the results of the ranging in "longs and shorts, rights and lefts."

The telephone operator in Central tabulates the readings submitted by the T stations, and places this data on the tables where both the plotter and computer can see it. The following is then the order of procedure:

PLOTTER	COMPUTER
Plots bursts on chart of equal parallax and equal direction: records the deviations *da* and *de*, and submits results to Computer.	Computes $M^1_1 — M_2^1$
	Finds value of $(DX-Q)$ from chart, for values of m_1 or m_2 (or both).
	Computes $E = da + (DX-Q)$ $e = de - DX\left(\frac{\pi}{20,000}\right)dU_0$
	Tabulates values of E and *e* and submits to telephone operator.

COMMENT

It is obvious that one of the principal weaknesses in the Telemetric System is the lack of check in the employment of only two observation posts, whereas with the use of three or more posts information would be obtained showing the error involved in observations. There would seem no good, reason, however, why three posts could not be arranged as a unit. The method of reading the horizontal angles would then have to be changed, so that the observations from the middle post could be used for the two bases. At present the only means of obtaining a check is to employ two separate bases for an adjustment, which necessitates the employment of two sets of computers and plotters.

In the matter of drift and wind correction, quite a good deal of time is consumed in determining these deviations, and, as will be noted in the example given, the amount of this correction is almost negligible. It would therefore seem proper to discontinue this particular method in obtaining these corrections, and, instead to formulate tabulated values for drift and wind deviations.

The observation instruments are, from the American Engineer's point of view, decidedly unsatisfactory, and, undoubtedly, range practice will develop important suggestions for changes. Along this line, it would be very desirable if an instrument could be designed suitable for flash observations, and, perhaps with additional appliances, also sufficiently accurate for observations on high bursts. The Flash Sections in the A. E. F. were, however, provided with two distinct types of instruments, which were employed for the particular mission desired—"spotting" enemy's guns or ranging on high bursts for friendly artillery.

Although the Telemetric System possesses the excellent point of merit of prescribing a definite routine for each step in the operation, many of these steps are, nevertheless, quite involved. In particular, the construction of the charts shown in Figs. 9 and 12, required for each adjustment, are quite involved and require considerable time for preparation. Shorter method for determining the same data can undoubtedly be developed when the system is operated with a view of improving method rather than arriving at actual results.

The main point, however, to be considered in the Telemetric System is that its operation requires a highly trained personnel, fully conversant with the trigonometric theory involved, and that it can not be employed, on short notice, as an alternative for any other method of ranging.

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A Repair with Aluminum Brazing Solder

Fort Adams, Newport, R. I., Aug. 14th, 1919.

THE EDITOR:-
Journal U. S. Artillery,
Ft. Monroe, Va.

The enclosed photograph will show the sealing of a fracture on the suction end of a Worthington Duplex Boiler Feed Pump, by PETERS ALUMINUM BRAZING SOLDER.

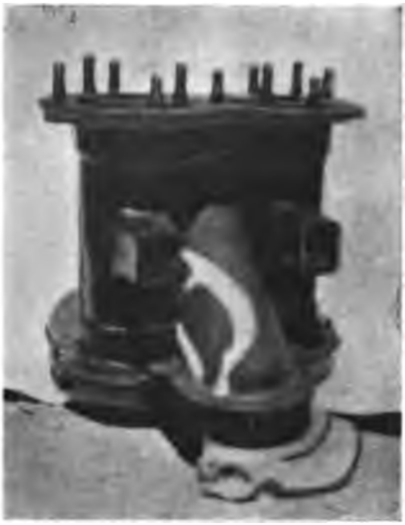

FIG. 1. 2178

This may be of interest to all Artillery Specialists who in the course of their professional career had occasion to contend with fractured gas engine cylinders.

The cylinders as shown in the photograph were totally unservicable and awaiting the action of comdemnation proceedings preparatory to be thrown on the junk pile. It was then determined to experiment with the Aluminum Metallic Filler, or Brazing Solder and applied to the manufacturer for a sample for the purpose of giving it a trial without any expense to the Government. Upon its receipt and acting on their suggestion a (v) shaped groove was cut the full length of the fracture and two small holes at the ends for the purpose of limiting its length; the only heat required was that furnished by a gasoline blow torch, but 300 degrees F. will be required to fuse the solder.

Upon completion of this work the cylinders were replaced and the water turned on viz., 60 lbs. per sq. in. With the exception of a few drops that appeared where the filler was applied and later on disappeared, the test was entirely satisfactory to all local engineers in the vicinity of those Coast Defenses.

John J. Mahoney
Engineer, C. A. C.

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Officers' Reclassification at Blois

Figures showing the disposition of officers ordered to Blois and reclassified are shown in the table printed below which includes all officers sent to the S. O. S. from combat organizations for reclassification because of unfitness for the duty on which they were engaged. The figures do not include many officers reclassified at corps or army headquarters or at G. H. Q., or wounded and disabled officers reassigned to duty. Of the 6304 Regular Army officers reaching France before Nov. 11, 1918, twenty in each 1000 were sent to Blois for reclassification. Of the 75,700 emergency officers, thirteen in each 1000 were reclassified at Blois. Higher standards of efficiency for Regular officers together with sudden promotion to positions of great responsibility have been cited to account for this difference.

	Assigned to S.O.S.	Returned to combat units.	Returned to U. S.	Total.
Regular Army	46	20	2	68
Regular Army (prov.)	43	8	11	62
National Guard	273	32	72	377
National Army	400	58	116	574
Total	762	118	201	1,081
Per cent.				
Regular Army	68	29	3	
Regular Army (prov.)	69	13	18	
National Guard	72	9	19	
National Army	70	10	20	
Total	70	11	19	

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BOOK REVIEWS

The Little Moment of Happiness. By Clarence Buddington Kelland. Harper & Brothers, New York. 7⅝"x5". 400 pp. Price, $1.50 net.

This is the tragic love story of a young and rather mysterious French woman, and an American cad, holding a Captain's commission in the American Army for the duration of the War. No doubt, there were many such men, who wore the Olive Drab, (and the type has been done full justice by the author), but we dislike to believe that Kendall Ware is a true American product. We believe, rather, that a youth, even of his parentage, and narrow training, after four years of university life, would have lost much of his fear of the "Presbyterian threshold."

Neither can one believe Andreè typifies French women, who, we learned during the war, were the solid rock upon which the security of France rested. The security of a nation does not rest on a beautiful face, or shapely feet, and the indulgence in "little moments of happiness." And we cannot believe that Maude Knox, reared on a mental diet of philosophy, would marry such a self-confessed, selfish cad, after he had turned down Andreè.

The characters of the story do not ring true, and leave a "dark brown taste," but the setting of the story, in war-time Paris, is shown feelingly and vividly, and inspires only sympathy for her great stress.

Captain Zillner. By R. J. Kreutz. New York. George H. Doran Co. 5¼"x7½". 326 pp. Price, $1.75.

The author of this book is said to be a former Austrian officer. The principal character, Captain Zillner, of the Austrian Army, is followed thru mobilization, to the Austro-Russian front, thru a short detail on staff duty—from which he is relieved and returned to his regiment for criticizing the useless sacrifice of men by his superiors—and to his wounding and loss of a limb, and leaves him finding peace in playing with children.

The book offers a gloomy picture of the lack of cohesion among the Austro-Hungarian nation, due, in great measure, to the racial differences between the various nationalities composing it. The army, again, suffers not only from this trouble, but also from the fact that the higher administrative staffs, which are nicknamed the "bottle-green" from the distinctive color of uniform worn, seem to be utterly incompetent snobs, who discuss the flavors of their "boeuf à la reine" and "oeufs pochès à la maitre," and order advances and retreats without regard to the tactical situations, or to the number of men sacrificed.

It might be noticed that of the two priests mentioned in the book one is a spy for the Russians, and the other is a despicable character, who attempts to refuse admittance to his church to wounded soldiers who happen to be Jews. The descriptions are as a rule vivid, and, in consequence, some are rather disgusting, particularly that of the test imposed upon Austrian ladies who seek entrance into the nurse corps.

Our Casualty and other stories. By George A. Birmingham. New York. George H. Doran Co. 5¼"x7¾". 280 pp. Price, $1.50.

An unusually clever collection of sixteen short stories, most of them dealing with some phase of the Great War. Those who have enjoyed some of the author's earlier stories will be reminded of "Spanish Gold" and "Lalage's Lover"; tho one gains the impression that the trial and travail of the war has left its mark upon the author, as it has upon us all, giving him a wider insight into human emotions. It may be noted that the author served as a Chaplain in the English forces, and saw service with the B. E. F. in France.

We of the service who have attended field maneuvers will appreciate the delicate sarcasm of "Getting Even"; "The Second Bass" takes us back to the entertainment huts of France, as witness "There's a drip of rain coming through the roof just there which will get you in the back of the neck every time you lean forward"; "Journey's End" is a clever description of war-time travel in France, and "A Gun-running Episode" and "Ireland For Ever" throw interesting side-lights on the Irish attitude, during their rebellion, toward proffered German assistance.

Tho the paper is rather poor, and the binding material of a low grade, the book is one that will while away a few hours in a very agreeable manner.

Motor Vehicles and Their Engines. By Fraser and Jones. New York: D. Van Nostrand Co. 6¼"x9". 352 pp. 278 il. Price, $2.00.

This book is one of the clearest and most complete manuals on the automobile, its engine, the operation, and care, that has ever been published. As stated by the publisher, and truthfully, too, it is a practical handbook on the care, repair, and management of motor trucks and automobiles for owners, chauffeurs, garagemen, and schools. Technical language has been avoided wherever possible. The book is at all times clear and simple, so that anyone can pick it up and understand it. The text is divided into 32 chapters on the gas engine, timing, fuels, elements of carburation, carburators (3 chapters), magnetism, elementary electricity, batteries, ignition system, magnetos, starting and lighting system, clutches, transmissions, running gears, tires and rims, how to drive, and the never-to-be-forgotten engine troubles, and "care and adjustment" (with tables). Moreover, the text is amply illustrated with diagrams and illustrations, colored in some cases for the sake of clearness.

It is a revision of "Motor Transportation for Heavy (Coast) Artillery," published by the Coast Artillery School during the war (1918), and compiled by Captain Fraser and Jones whose previous experience combined with pointers acquired from their teaching in the Motor Transportation Course of the Coast Artillery School, makes them unusually well qualified to prepare such a text. Captain E. S. Fraser is with the American Bosch Magneto Co. and Captain Ralph B. Jones is with the Willys Overland Co.

"Motor Vehicles and Their Engines" should be owned by everyone at all concerned with automobiles.

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CURRENT ARTILLERY LITERATURE

Advance Base Mines and Mining.—The Marine Corps Gazette, Sept., 1919 p. 221

Airplane Mapping by the United States Army Yankee Airplane Mappers Studying and at Work; a War-time Accomplishment Suited to Days of Peace.—Scientific American Supplement No. 2283, October 11, 1919, p. 213.

Army We Need, The.—The North American Review, November, 1919, p. 645.

Awakening of Albania, The.—The Geographical Review, August, 1919, p. 73.

Divisional Engineer Officer and His Relation to the Artillery and Infantry, The.—Professional Memoirs, Sept.-Oct., 1919, p. 602.

Heavy Coast Artillery.—Journal of the Western Society of Engineers, June, 1919, p. 375.

Lest We Forget..—The price we paid for being unprepared. The enormous losses among untrained troops. A startling case for universal training.—*The Worlds Work,* November, 1919, p. 33.

Natural Features of the South Atlantic Coast, With Special Reference to Savannah Harbor.—Professional Memoirs, Sept.-Oct., 1919, p. 505.

Optics of the Air.—Journal of the Franklin Institute, Oct., 1919, p. 433.

Responsibilities and Duties of Naval Officers of the United States in Educating and Informing the Public on Professional Matters.—United States Naval Institute Proceedings, October, 1919, p. 1751.

Telemetric System of High Burst Ranging, The.—Professional Memoirs, Sept.-Oct., 1919, p. 543.

Testing Rifle Ammunition.—25,000,000 shots fired annually by a great factory to insure standard quality.—*Scientific American Supplement No. 2283,* October 11, 1919, p. 221.

* * *

BOOKS CATALOGED
DURING THE MONTH OF SEPTEMBER, 1919
Library, Coast Artillery School
Fort Monroe, Va.

Above the French Lines	Walcott, Stuart
Armenia and the War	Hacobian, A.P.
America's Attitude Toward the War	Bankers Trust Co.
America's Munitions 1917-1918	U.S. War Dept.
Annual Report	U.S. Advisory Committee for Aeronautics.
Attack	Liveing, E.G.D.
Battering the Boche	Gibson, Preston
Best O' Luck	McClintock, Alexander
Bottled Up in Belgium	Maurice, A.B.
Britain in Arms	Destree, Jules
Britain Transformed	London, T.F.Irwin,
Brothers in Arms	Powell, E.
Business of War, The	Marcossen, I.F.

Canteeners, The	Dixon, Agnes M.
Cleveland Era, The	Ford, Henry J.
Colonial Folkways	Andrews, Chas. McL.
Complete Handbook for the Sanitary Troops of the U.S. Army and Navy, A	Mason, Charles F.
Comrades in Courage	Redier, Antoine
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Course in Field Gunnery, A	U.S. School of Fire For Field Artillery.
Daredevil of the Army, The	Corcoran, A.P.
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JOURNAL OF THE UNITED STATES ARTILLERY

Published under supervision of the Coast Artillery Training Center Staff, by direction of the Chief of Coast Artillery.

12 numbers per year; volumes begin January and July. Issued on 15th day of each month.

Entered at the Post Office at Fortress Monroe, Va., as second class matter.

Subscription price, per annum:

Domestic	$3.00
Canada	3.25
Countries in the postal union	3.50
Single numbers	0.30

All subscriptions payable in advance.

Subscriptions may be entered to begin with any desired issue of the Journal. It is suggested that those who have not the numbers beginning with January, 1919, will find it desirable to begin with that issue, as all the numbers from there on are filled with especially live, important matter.

Make checks, drafts, and postal orders payable to JOURNAL U. S. ARTILLERY.

Remittances, articles intended for publication, and communications relating to the management should be addressed JOURNAL U. S. ARTILLERY, Fort Monroe, Virginia.

It is earnestly requested that prompt information be given of changes of address, or failure to receive the JOURNAL. Both old and new addresses should be given.

LIEUT. COL. F. S. CLARK, C. A.
Manager and Editor

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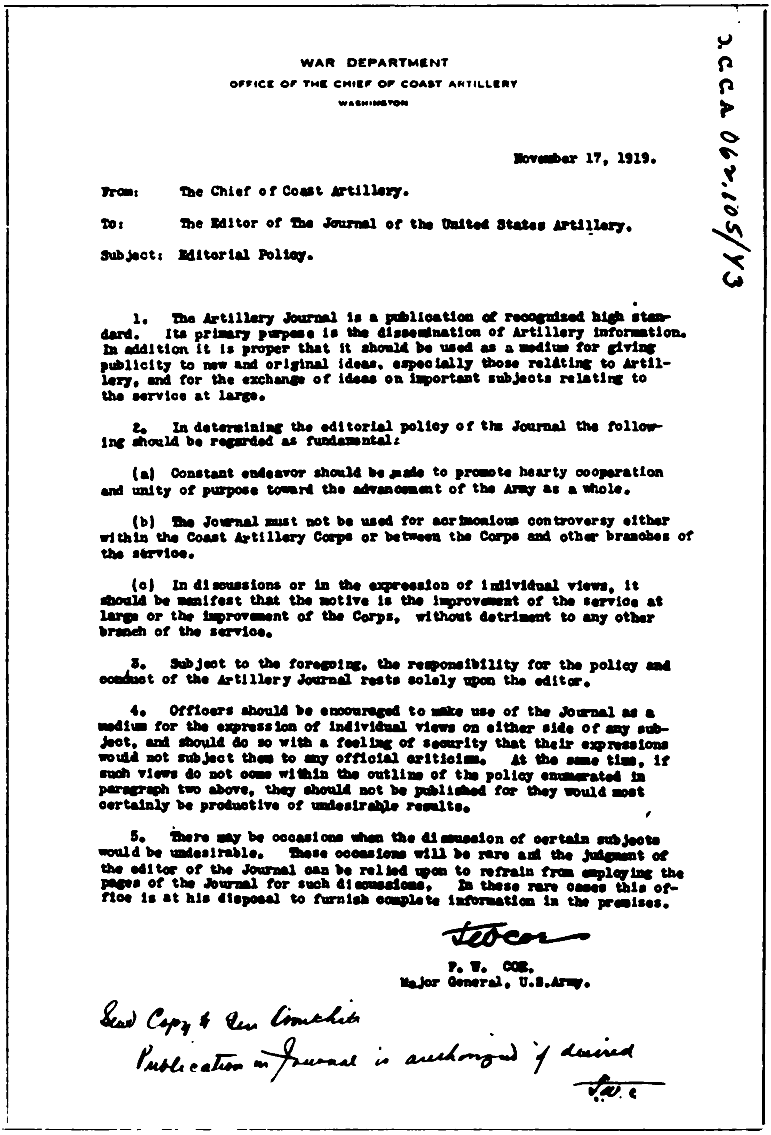
London Agents:
B. F. Stevens and Brown, 4 Trafalgar Square

FOR THE ATTENTION OF ALL JOURNAL READERS

The letter reproduced below constitutes an explicit charter governing the functions and limitations of the JOURNAL of the UNITED STATES ARTILLERY. It is believed that the presentation of this statement of the Chief of Coast Artillery will make clear to all readers the extent to which reliance may be placed in the repeated editorial assertion that "the pages of the JOURNAL are available for free and open discussion of all matters affecting the Coast Artillery Corps".



WAR DEPARTMENT
OFFICE OF THE CHIEF OF COAST ARTILLERY
WASHINGTON

O.C.C.A 062.105/Y3

November 17, 1919.

From: The Chief of Coast Artillery.

To: The Editor of The Journal of the United States Artillery.

Subject: Editorial Policy.

1. The Artillery Journal is a publication of recognized high standard. Its primary purpose is the dissemination of Artillery information. In addition it is proper that it should be used as a medium for giving publicity to new and original ideas, especially those relating to Artillery, and for the exchange of ideas on important subjects relating to the service at large.

2. In determining the editorial policy of the Journal the following should be regarded as fundamental:

(a) Constant endeavor should be made to promote hearty cooperation and unity of purpose toward the advancement of the Army as a whole.

(b) The Journal must not be used for acrimonious controversy either within the Coast Artillery Corps or between the Corps and other branches of the service.

(c) In discussions or in the expression of individual views, it should be manifest that the motive is the improvement of the service at large or the improvement of the Corps, without detriment to any other branch of the service.

3. Subject to the foregoing, the responsibility for the policy and conduct of the Artillery Journal rests solely upon the editor.

4. Officers should be encouraged to make use of the Journal as a medium for the expression of individual views on either side of any subject, and should do so with a feeling of security that their expressions would not subject them to any official criticism. At the same time, if such views do not come within the outline of the policy enumerated in paragraph two above, they should not be published for they would most certainly be productive of undesirable results.

5. There may be occasions when the discussion of certain subjects would be undesirable. These occasions will be rare and the judgment of the editor of the Journal can be relied upon to refrain from employing the pages of the Journal for such discussions. In these rare cases this office is at his disposal to furnish complete information in the premises.

F W Coe

F. W. COE,
Major General, U.S.Army.

Send Copy to Gen [illegible]
Publication in Journal is authorized if desired
F.W.C.

Frontispiece.

U. S. S. NEW MEXICO

JOURNAL

OF THE

UNITED STATES ARTILLERY

VOL. 51, No. 6. DECEMBER, 1919 WHOLE No. 160

Counter-Battery, the Principal Mission of Corps Artillery

By Col. R. M. Mitchell, C. A., Counter-Battery Officer, 4th Corps, A. E. F.

The cessation of hostilities on the eleventh of November, 1918, found our (American) armies still developing methods and systems for applying counter-battery action to best advantage. At that time no standard organization for conducting this important work had been developed but plans for one were rapidly crystallizing in the minds of officers who had given this subject their especial attention. As a result of their experience, counter-battery officers were daily introducing minor changes looking toward the perfection of their system, when their work was brought to an abrupt termination by the armistice, and the movement on Brest succeeded that against Metz. Our experience and that of our Allies had convinced Artillery Commanders that the counter-battery policy was sound, and they had unhesitatingly adopted it, but an organization to put this policy on an efficient working basis had been only tentatively prescribed, and, so far as I know, that is its present status. It is, therefore, with an organization for conducing counter-battery work in accordance with an adopted policy, rather than with the policy itself that this article is concerned.

Possibly a brief resumé of counter-battery development in this most recent and greatest war will be of interest.

The principles of counter-battery work are not new, but like the rules of strategy and the sound principles of tactics enunciated and practiced by Napoleon, have come down to us from his time unchanged. The tremendous development made in Artillery matériel during the past twenty years, and the introduction of large caliber field guns and howitzer and "special mission" guns has opened up so many new possibilities in artillery action, that during the first years of the war we find both sides seemingly diverted from basic principles, and, so far as artillery action is concerned, concentrating their efforts on special missions and reprisals. After the first retreat from the Marne and the subsequent stabilization of the lines, each side, to gain a temporary advantage and protect itself from the enemy's rifle and machine gun fire, "dug in." These trenches, at first rather crude, were gradually improved and ultimately became very elaborate and of great strength, effectively nullifying the fire of small arms and rendering the advance of either side a very difficult matter, accomplished only at great sacrifice of life. As a natural result, artillery was called upon to destroy these works which were impeding the advance and the "artillery preparation" and "counter preparation," as we know them had their birth. This was good, so far as it went, but even with the enemy's works destroyed, his artillery, still intact, inflicted frightful losses upon the advancing Infantry. The next step was the introduction of the "creeping" or "rolling barrage," behind and close to which the Infantry advanced with comparative security, "mopping up" as they went. This brought forth the "counter barrage" to prevent the Infantry advance or render it very costly. For considerable time, then, we find preparation answered by counter-preparation and barrage by counter-barrage, the Infantry in every instance receiving most of the punishment with an attendant lowering of morale and loss of confidence in their Artillery as an efficient auxiliary. It required two years of very costly experience before either side awoke to the old combat principle that it is slaughter to push Infantry forward so long as the enemy's Artillery is in position and un-silenced. They seem to have overlooked the lessons which all wars have taught and to have forgotten that in times before the fire intensity of weapons had been developed to its present wonderful state (and as a consequence the value of cover was not so well understood) armies coming into combat would halt their Infantry just beyond effective artillery range and an artillery duel would then ensue, the result of which frequently decided the outcome of the battle. The British were the first to realize that to rid their Infantry of the demoralizing punishment inflicted by the enemy's Artillery, they must destroy or neutralize his *Artillery* and in the latter part of 1916 they inaugurated systematic counter-battery work along their entire front. From the results obtained the importance of this step was evident at once, and in February of 1917 the British War Office published an Artillery Note on "Counter-Battery Work," covering organization and command, allotment of Artillery, methods of locating and recording the positions of hostile batteries, principles of action and methods of keeping records. This was known as "Artillery Notes No. 3," issued by the General Staff at British G.H.Q. and revised in February 1918 as the result of a year's experience and trial.

Coincident with the adoption of systematic counter-battery work, came the development of the Artillery Information Service, which was placed under the control of the Counter-Battery Officer. The necessity for obtaining accurate information concerning the enemy's Artillery, brought forth several new means and devices which had not before been given serious consideration. Most notable of these are the systems and devices used in flash spotting and sound ranging, and the personnel charged with this work were very properly placed under the Counter-Battery Officer for tactical employment. But by far the most valuable aid to Artillery action and the most definite means of gaining information concerning the enemy were furnished by the Air Service and the importance of their work cannot be overestimated. At the beginning of the war the scarcity of aviators and even more so the lack of sufficient aeroplanes, prohibited the assignment of aerial units for exclusively Artillery missions, although the advisability of such assignment was manifest from the start; but as soon as the production of aeroplanes in large numbers was accomplished and sufficient trained pilots and observers were available, we find (in our own armies, at least) aero squadrons attached to Corps Artillery units for exclusively Artillery missions.

Briefly, the functions of the Air Service in connection with counter-battery work may be summarized as: (a) reconnaissance, (b) photography, and (c) ranging. Under (a) we place the spotting of enemy batteries in action, the results of which are immediately sent by radio to the Counter-Battery Office in order that the battery, while active, may be engaged and silenced by one or more of our own. Under (b) the whole of the enemy's line on the Corps front is photographed from the air and a careful study of these photographs gives confirmation as to battery locations, kinds of cover and camouflage employed and much other valuable information, which enables us to predict the enemy's movements with considerable accuracy. By means of photographs also, the progress made in destroying enemy batteries and works can be followed and the accuracy of our firing checked. Under (c) the Air Service gives us the means of conducting destructive fire by accurate observation of the shots. Indeed, in these days when concealment is of such great importance and indirect fire is the rule rather than the exception it would be virtually impossible to conduct successful fire for destruction without the aid of the Air Service.

The effect upon the enemy of the pursuit of any policy is naturally the most potent factor in deciding upon the continuance of that policy and the following extracts from captured German documents are therefore of particular interest in considering the results obtained by systematic counter-battery work:

Extracts from a memorandum issued by the 4th Res. Div. dated 25th July 1918, on the situation on the GAVERELLE front:

(a) "*Artillery.* There are a very large number of hostile destructive shoots. The enemy replies very quickly and with a large expenditure of ammunition on batteries which are annoying him, particularly when his own artillery is fired at. Even roving guns and batteries firing from alternative positions are frequently found by him and immediately engaged.__The movement of even the smallest parties of troops is seen and fired on."

(b) "C. G. S. of the Field Army. II. No. 93577 op. 1/8/18. An accurate record of the wastage in heavy and field artillery material gives the following interesting result: In one month the enemy's fire has completely destroyed in round numbers 13% of the pieces taking part in active operations. This figure clearly brings out the value of presistent counter-battery work. Consequently I request that measures be taken to assure that on our side also *all available means are employed* to carry on the artillery battle with all possible energy. Attention is again drawn to the memorandum already issed to this effect, with reference to the intersection of positions, the accuracy of maps, the employment of aeroplane and balloon observation, deliberate shooting with single guns, etc.

Sgd LUDENDORFF"

Since the protection of our Infantry depends so largely upon the thoroughness of our counter-battery work, the importance of perfecting and standardizing an organization to handle this work is manifest. A counter-battery programme involving systematic fire for destruction should be part of the daily work of Corps Artillery when in active operation against an enemy, but most important of all, means and facilities must be available for the *immediate* neutralization of hostile batteries as they come into action and considering an organization to accomplish this, the necessity of placing the Artillery Information Service (A.I.S.) and specially designated aero squadrons and balloon companies under the Counter-Battery Officer for tactical control, is at once apparent. The principal points to receive consideration before reaching conclusions as to an appropriate counter-battery organization, are as follows:

1. What is the most suitable unit to be charged with counter-battery work?
2. Will separate batteries or groups be allotted for this work by the Commanding General of the unit selected; if so, will such allotment be made daily, or for some other period of time, or permanently?
3. Should the Counter-Battery Officer be an officer on the Staff of the Chief of Artillery of the unit selected, or should he command the units ordinarily employed in counter-battery work?
4. What authority and latitude should be relegated to the Counter-Battery Officer in the performance of his functions?
5. How should the counter-battery duties be distributed and what office force should control the work?
6. What means of liaison are necessary?
7. Will the organization adopted lend itself readily to the performance of counter-battery work as well in war of movement as on stabilized fronts?

Considering each point in the order given:

1. The most suitable unit to control counter-battery work is the Corps. The front covered by a Division is ordinarily too narrow and the divisional artillery too light and of too short range to handle this work effectively and its logical employment is in support of its own Infantry and against the personnel of the enemy. Occasions arise when field guns and howitzers can be used to advantage for neutralization, particularly against the enemy's forward artillery of similar classes, and these opportunities should not be neglected; but usually the bulk of counter-battery work must be undertaken by batteries of 6-inch caliber or greater, generally the heavier the better, if firing for destruction. On the other hand, the Army is too unwieldy a unit to control this work and would experience

considerable difficulty in collecting and tabulating the detailed information as to enemy artillery activity necessary for the successful employment of counter-batteries on its entire front. Furthermore, information and orders could not be transmitted from the Army to counter-batteries with sufficient rapidity to be of real value for any but the most deliberate operations without the installation of a prohibitively elaborate telephone service and the employment of a large force to keep it in operation and repair. We therefore arrive at the conclusion that the Corps is the most suitable unit for handling this work and it should be charged with *all* the counter-battery work undertaken upon its front, regardless of the caliber of batteries employed or whether they pertain to the Army, Corps, or Divisional Artillery.

2. The number of batteries to be used at any time for counter-battery work depends upon the number of active batteries which the enemy has upon a given front, the degree of their activity, the character of their protection, their location and the character of operations projected. Since all of these conditions are variable, the number of counter-batteries required must be variable and no fixed number or percentage of batteries can logically be told off as counter-batteries. Conditions as they exist at any particular time and in a given area must decide this point, otherwise we may find that either insufficient preparation has been made for neutralization, or certain batteries are remaining idle, or perhaps needlessly expending ammunition.

During periods of active operations (which must be more or less spasmodic on any particular front, depending upon plans and orders of the Supreme Commander), the counter-battery plan must be a part of the general scheme and carefully coordinated with the other features of the operation. This general scheme, however, should, and undoubtedly will always include a liberal reserve of batteries for counter-battery action as the enemy discloses batteries of his which have before been silent.

3. The question as to whether the Counter-Battery Officer should be a staff officer of the Corps Chief of Artillery or the Commander of the Corps Heavy Artillery is one of those points which was not definitely settled in our Army at the time of the armistice and the advocates of each arrangement can support their claims with logical reasons. Let us assume that the Counter-Battery Officer is a staff officer, which virtually

makes the Corps Chief of Artillery the Counter-Battery Officer, for a staff officer is merely the mouthpiece of his chief. The advantages of this arrangement are:

(a) Close liaison between C.-B. O., Chief of Corps Artillery, Chief of Staff Corps Artillery, G-3 Corps Artillery and all of Corps headquarters;

(b) Single information service (A. I. S.), with central receiving and distributing point at Corps headquarters;

(c) Since all counter-battery orders emanate from Corps headquarters, the matter of employing divisional artillery units for counter-battery work is accepted without question by commanders of those units, and misunderstandings and friction avoided.

The disadvantages are

(a) It places about 75% of the activities of the Corps heavy Artillery and frequently those of the divisional artillery under actual control of an officer inferior in rank to the commanders of those units.

(b) It minimizes the duties of the Heavy Artillery Commander (who is usually a brigadier general and an officer of wide artillery experience) by depriving him of actual command or original action and initiative in about 75% of the activities of his units.

(c) For counter-battery neutralization (which represents the bulk of the work), the Heavy Artillery Commander might not be even aware of what his units were doing until after their work had been accomplished, since in the necessity for immediate action the C.-B. O. is (and should be) authorized to call directly upon any sub-division (group or battery) to open with neutralizing fire.

Assuming that the Heavy Artillery Commander is C.-B. O., we have the following advantages:

(a) The Heavy Artillery Commander becomes so in fact instead of only in name as in the case of the first assumption.

(b) The Artillery most employed as counter-batteries is commanded by an officer of appropriate grade and experience and one familiar with the capabilities of his armament.

The disadvantages are:

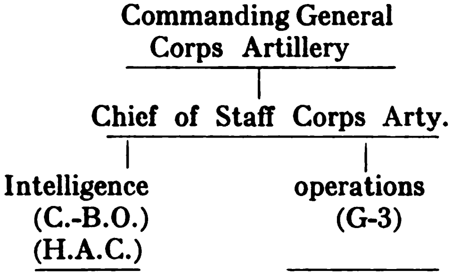
(a) Duplication of A. I. S., for it is absolutely essential that the C.-B. O. get all information as to enemy artillery activity at the earliest possible moment, and it is not probable that the Corps Chief of Artillery will sanction the removal of his A. I. S. headquarters from the vicinity of his P. C.

(b) It increases the difficulties of liaison between the C.-B. O., the Corps Chief of Artillery and Corps headquarters.

(c) It may result in divisional artillery commanders questioning the judgment of the C.-B. O. when they are required to expend, for emergency counter-battery work, ammunition which they have drawn and are saving for other projected operations.

(d) The difficulties of co-ordinating artillery operations are increased.

The British, whose organization and methods of liaison are particularly well adapted to it, have decided upon a staff officer as counter-battery Officer, but such officers are selected from among their most experienced and competent artillerists in the grade of Lieut. Colonel. So far as our army is concerned, a study of the pros and cons of this question leads one to the conclusion that a compromise is not incompatible with the best interests of the service, but on the contrary the advantages of both arrangements can be secured and most of the disadvantages eliminated by making the Heavy Artillery Commander the C.-B. O. and combining his P. C. with that of the Corps Chief of Artillery. Since the Heavy Artillery Commander (H. A. C.) would probably also command a brigade of heavy artillery, his brigade staff, augmented by such additional officers and men as conditions warranted, would take over the counter-battery duties of the Corps. The following liaison diagram illustrates the advantages of this method:



4. The C.-B. O. should be given all possible latitude in the performance of his work. He should take orders direct from the Commanding General, Corps Artillery, with whom he should discuss his work daily, in order to carry out the latter's ideas and policy. As representing his Chief he should be authorized to deal directly with artillery brigade and grouping

commanders (and even with group commanders, when necessary) of all artillery operating in the Corps area, whether it pertains to the Corps, Division, or to the Army. Such authority is essential in order to obtain quick action and neutralize enemy artillery fire as fast as it develops.

5. A proper discussion of this requires a statement as to what are counter-battery duties. Briefly, it is the function of counter-batteries to keep the enemy's artillery in a state of subjugation. The following quotations from British Artillery Notes No. 3 outline the duties very clearly:

> "The characteristics of counter-battery work are two-fold, destruction of hostile batteries as a daily task and neutralization on certain tactical occasions of all batteries which it has not been possible to destroy.
>
> "Destruction, as already stated, must be regarded as a continuous procedure. It is to be carried out at all times with relentless vigor, both during actual battles and in the intervals between them.
>
> "It is evident that destruction offers the most satisfactory means of reducing the hostile artillery to impotence; but since this ideal cannot be completely achieved, occasions will arise in all active operations when the Infantry must be further protected against the enemy's guns by fire of neutralization."

In order to carry out this work, the C.-B. O. must be thoroughly familiar with the capabilities and possibilities of his own artillery and that of the enemy. He must study the enemy's organization and methods and be able to predict with reasonable accuracy what counter-action will be taken by him on any original action by us. He should so plan his programme as to keep all elements of the enemy's artillery in a state of perpetual discomfort and anxiety by delivering sudden bursts of fire at odd and unexpected moments, first on one battery and then on another and without any regularity. He must have the situation so well in hand that at any time he can deliver a smothering fire upon any unit of the enemy's artillery before it has been able to inflict material damage upon our troops. In other words, he must by means of his initiative and activity and the perfection of his information service, maintain artillery superiority.

To accomplish this, the C.-B. O. must have tactical control of the A. I. S. and must keep records of enemy artillery activity, both on maps and by means of books and photographs. The following organization of a Corps Counter-Battery Office, based upon our own experience and the way this matter was handled by the British, is suggested:

Counter-Battery Officer Heavy Artillery Commander	Brigadier General
2 Aides*	1st Lieutenants.
1 Chief of Staff	Lt. Col. or Major,G.S
1 Chief of A. I. S.	Lt. Col. or Major.
1 Asst. A. I. S.	Captain
1 Photograph Expert	Captain or Lieutenant
1 Adjutant	Captain
1 Personnel Adjutant	2nd Lieutenant.
1 C.-B. Operations Officer	Lt. Col. or Major
2 Asst.C.-B. Operations Officers	Captains
4 Liaison Officers	Captains or Lieutenants
1 C.O., Headquarters Det.	Captain
1 Signal Officer	Captain or Lieutenant
1 Surgeon	Captain or Lieutenant
1 Field Clerk	

The Headquarters Detachment would consist of:

1 Sergeant Major, Sr. Gr.
2 Sergeants Major, Jr. Gr.
2 Electrician Sergeants (1st or 2nd cl.)
2 Master Gunners
3 Radio Sergeants
1 1st Sergeant
1 Supply Sergeant
1 Mess Sergeant
5 Sergeants (Chauffeurs)
25 Corporals (18 Chauffeurs, 4 Hq. Clerks, 1 Company Clerk, 1 Tel. Switchboard Operator and 1 Panel Operator.)
2 Mechanics
2 Cooks
1 Bugler, 1st cl.
1 Bugler
18 Privates, 1st cl.(2 Tel. Switchboard operators, 2 Panel operators, 10 Messengers, 4 Linemen.)
20 Privates (14 Orderlies, 6 Duty.)

Total 87 Enlisted

The following diagram illustrates this organization more clearly:

---

* The general will use his aides for any duty he may decide upon, but ordinarily they could be well employed in inspection and liaison work.

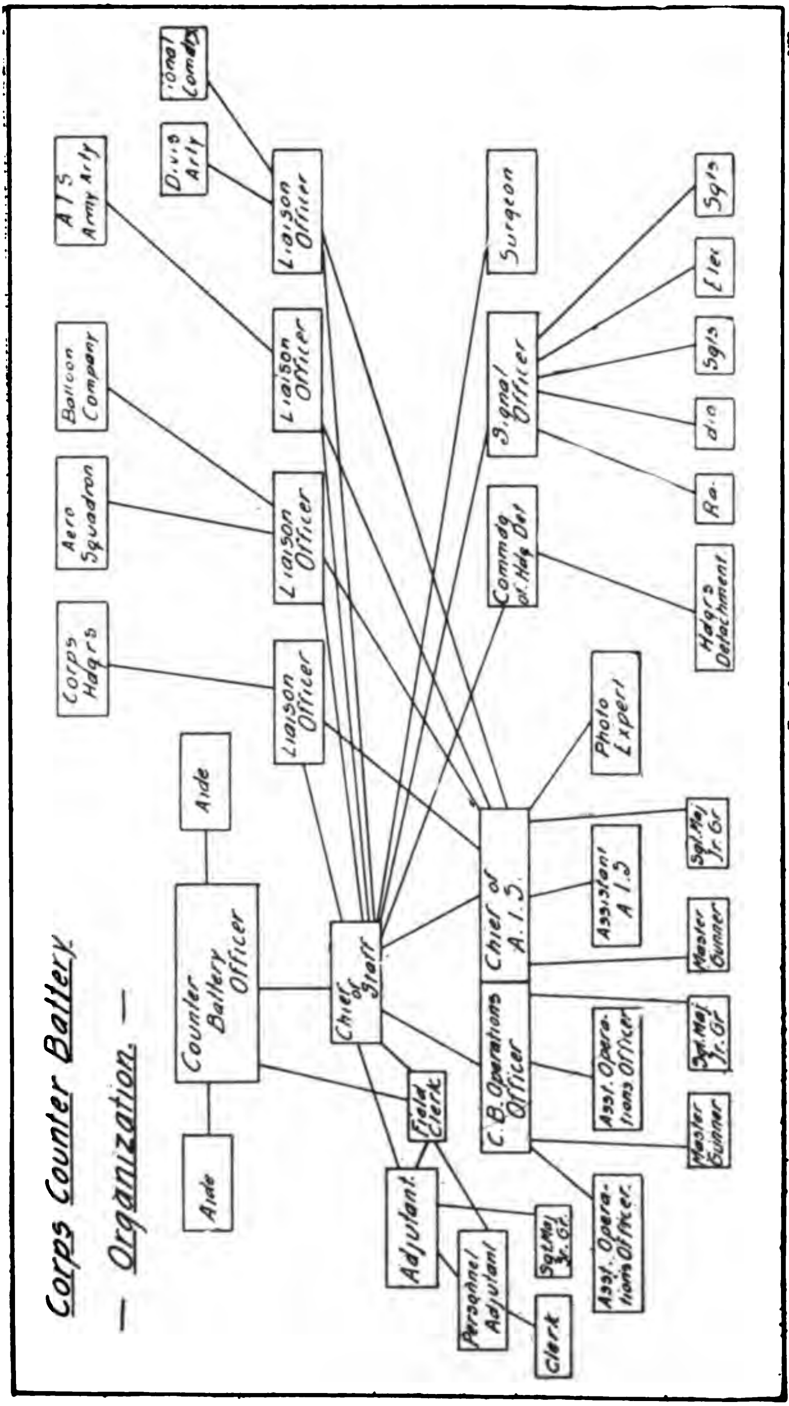

Corps Counter Battery
— Organization. —
Aide
Counter Battery Officer
Aide
Chief of Staff
Field Clerk
Adjutant
Personnel Adjutant
Sgt. Maj. Jr. Gr.
Clerk
Corps Hdqrs
Aero Squadron
Balloon Company
A.T.S. Army Arty
Divis Arty
ional Comdrs
Liaison Officer
Liaison Officer
Liaison Officer
Liaison Officer
Surgeon
Signal Officer
Commdg Of. Hdq Det
Hdqrs Detachment
Ra.
dio
Sgls
Elec
Sgls
Photo Expert
Chief of A.I.S.
Assistant A.I.S.
Sgt. Maj. Jr. Gr.
Master Gunner
C.B. Operations Officer
Asst. Operations Officer
Sgt. Maj. Jr. Gr.
Master Gunner
Asst. Operations Officer.

Fig. 1.

Specifically, the duties may be apportioned and stated as follows:

The C. B. O.

Commands and directs operations of
- (a) Corps Heavy Artillery
- (b) The Artillery Brigade which he commands
- (c) The Corps C.-B. work
- (d) The Corps A. I. S.
- (e) The Aero Squadrons and Balloon Companies assigned for Artillery missions.

The Chief of Staff

Co-ordination of the work outlined for C.-B. O.

C.-B. Operations Officer and his Assistants

- (a) Direct aerial reconnaissance, photography and ranging of C.-B. Aero Squadrons and Balloon Companies.
- (b) Prepare and keep up to date C.-B. Operations maps. Prepare plans for C.-B. action in case of advance or withdrawal.
- (c) Order all C.-B. action (1) Destructive
  (2) Neutralizing
- (d) Keep records of all C.-B. orders.

Chief of A. I. S., Asst. A. I. S. and Photograph Expert

- (a) Direct movements of Flash and Sound Ranging Sections.
- (b) Collect and distribute information concerning enemy artillery and artillery activity.
- (c) Keep history of enemy batteries and all C.-B. work upon them.
- (d) Keep maps, etc., up to date showing locations of enemy artillery, degree of activity, sectors of fire, areas fired upon, etc.
- (e) Examination, classification and filing of aeroplane photographs and tabulation of information obtained from them.

Adjutant

- (a) Filing and records of Corps H. A., the Artillery Brigade, and C. B. Office.
- (b) Periodical reports and returns as required.
- (c) All administrative and other work not otherwise allotted.

Personnel Adjutant

Personnel records as for other organizations.

Liaison Officers

One to operate between G-2 of the Corps and the A. I. S. office.

One to divide his time between the C.-B. office and the aerodomes of aero squadrons and balloon companies assigned to C.-B. work. This man should be a bright, tactful artilleryman, of pleasing personality and should be a rated aerial observer. He should be in close touch with all C.-B. work, which he should discuss with the officers of the Air forces and by stimulating their interest in it insure their closest co-operation.

One divides his time between the A. I. S. of the Army Artillery and the A. I. S. of the Corps, exchanging information.

One is charged with the duty of keeping divisional artillery commanders informed of the C.-B. situation and projects, with the idea of obtaining their closest co-operation.

C. O. Headquarters Detachment

Same as for similar units at other headquarters.

Signal Officer

Supervision of radio and telephone work and maintenance.

Surgeon

Duties of Brigade Surgeon.

6. In periods between operations and on stabilized fronts *all* batteries in a Corps area should be considered available for C.-B. work as required and should be subject to the order of the C.-B. O. at any time except when actually engaged in other firing. To accomplish this without friction and without interference with the plans formulated by the operations sections of the Corps Artillery, the closest liaison must exist between that section and the C.-B. office. These two should have adjoining offices in the same P. C. and should discuss their daily programmes together and with the Chief of Staff, Corps Artillery. However, the C.-B. O. should normally have priority in calling upon any unit for action and, it being essential that he have authority to call directly upon any battery,

group or grouping located in the Corps area for appropriate action, his supply of telephones and telephone connections must be liberal.

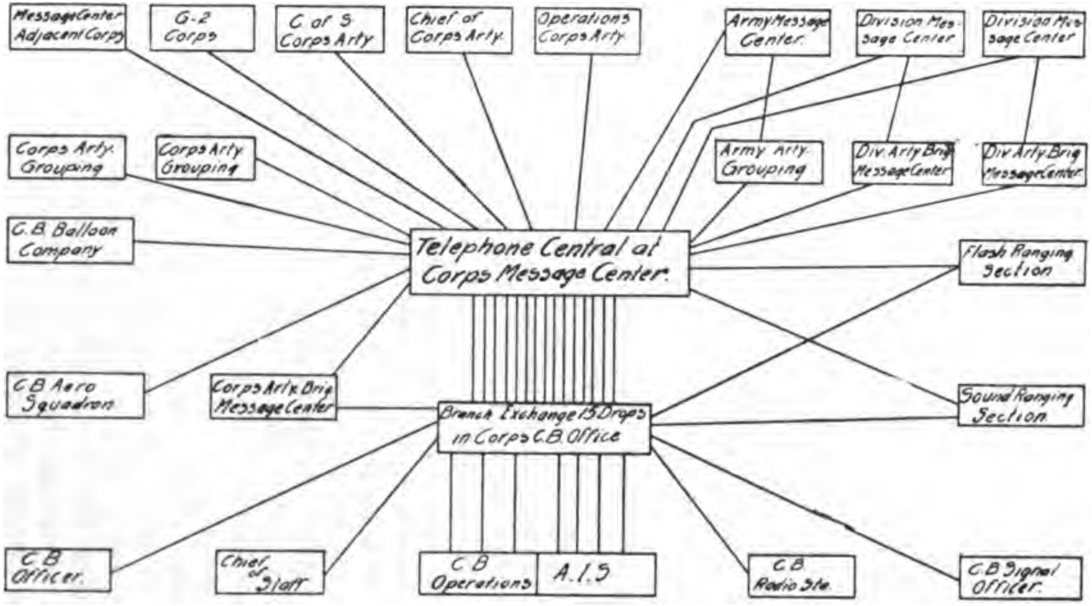
The connections shown in the diagram (page 569) are suggested as being appropriate.

Complete connections for C.-B. office *only* are shown in the diagram.

In addition to telephone liaison, the importance of maintaining liaison officers has been developed by the late war and needs no further discussion here. For this reason four liaison officers are contemplated in the organization submitted and their proper functions have been previously outlined.

7. In answer to this question, it may be stated that the principles of counter-battery work remain the same in war of movement as in war of position. Whatever the policy or organization adopted, the break from war of position to that of movement will introduce many obstacles to the successful prosecution of counter-battery work, which the C.-B. O., by the exercise of energy, initiative and resourcefulness must overcome. However, it must be remembered that the same conditions which hinder our obtaining information upon which to act make it difficult for the enemy also. The one most important feature in the conduct of active operations is the maintenance of liaison, including systems of communication, and it is also the most difficult. An advance presents greater obstacles than a retirement, for in the latter case previously selected positions can be occupied successively and the back area systems of communication, usually intact, become immediately available, while in the case of an advance all new positions must be reconnoitered, usually under fire, and new lines of communication installed.

Let us consider an advance. What can be done in counter-battery work after the enemy's artillery has commenced its rearward movement? Our flash rangers soon find themselves too far back to be of use and must advance to new positions. This requires a minimum of about two days for each move before the system is again ready for work. The sound ranging sections become practically useless when our own artillery activity is materially increased (as it would be in supporting an advance) and these organizations are confronted with the necessity of a move also, a difficult task, particularly over shell torn ground, on account of the weight of the central apparatus and the time required to dismantle and assemble it.



Complete Connections for Counter Battery Office only are shown in the above Diagram.

FIG. 2.

2478

During the advance on St. Mihiel, a French Corps required five days to move its sound ranging section one bound and put it in operation on a new front. With our superior facilities for transportation, we can lower that time, but in any event three days is the minimum that could be counted upon.

The whole artillery telephone system must be moved forward, centrals established, lines run and connections made, and this requires time.

Our own artillery is on the move and the exact positions of our units are not known to the C.-B. officer and will not be until communication with them has been established.

The enemy's artillery positions are not known until disclosed by firing and picked up by reconnoitering aeroplanes.

Carefully prepared counter-battery maps immediately become useless and new ones cannot be made until stabilization results after the advancing waves of our army have exhausted their momentum against the enemy's gradually stiffening resistance.

During the early stages of our operation, before the enemy's artillery has moved, counter-battery action is pursued in accordance with the Artillery Plan of the Corps Commander; but after the movement is well under way, deliberate firing ceases and sole reliance must be placed in guns and howitzers of *long* range (which must be moved forward in echelons and not all at once) and in aeroplanes which spot the flashes of the enemy guns as they are fired and report their locations by radio. Then each battery which has halted and is oriented, and can reach the locations given by the planes, should be required to open with neutralizing fire on such points for a definite period of time at the maximum rate.

Thus counter-battery action in war of movement becomes virtually automatic.

The principles are the same in a rearward movement as in an advance. In such a movement the re-location of O. P.'s, transfer of apparatus and batteries and installation of systems of communication offer fewer difficulties than in an advance, but the small advantage thus resulting is more than offset by the *decrease in morale of the troops.*

The importance of initiative in counter-battery work cannot be over-estimated, particularly in deliberately planned firing. The side which opens first on its opponent's artillery, finds itself master of the artillery duel unless the opponent has great superiority in number of guns; for, assuming reasonably accurate work, artillery under counter-battery fire cannot come into action until such fire has ceased, the resulting damage repaired and the gas cleared away.

Counter-battery affords the surest protection of our Infantry from enemy artillery action.

Automatic Counter-Battery

The following scheme, taken from a similar system adopted by the British, was devised for use in one of the Corps of our Army just prior to the armistice and is based upon co-operation between the Air Service and the Artillery.

The map used was the 1/20,000 map of the area being covered by the aviator, who upon definitely spotting an enemy battery, particularly one in action, immediately sent a zone call by radio, locating the battery by its hectometric co-ordinates.

(1.) Each kilometer square is a separate zone and will be designated by the aviator as given on 1/20,000 map, for example C-39, X-41, D-08, etc.

(2.) After sending the zone, the aviator designates the hectometric co-ordinates, as for example C-39 35 98.

(3.) Each battery receives this on its radio set and translates it as follows: C 39/3.5—9.8, and each battery having a field of fire which includes the point designated (unless it is at the extreme edge of its field of fire) will fire two rounds per gun on the designated target at an ordinary rate of fire.

(4.) If the aviator believes that a heavy concentration is not necessary, as for example when an isolated 77 mm. gun is the target he will send C 39 35 98 P when only one platoon of each battery will respond as above.

(5.) If, on the contrary, a very heavy concentration is considered desirable as when a heavy roving gun is discovered in action, or during war of movement when it is necessary to pound the enemy batteries particularly hard every time they show themselves in action, the aviator will send C 39 35 98 R when every battery that is oriented and can reach the target will fire upon it at its most rapid rate for three (3) minutes.

(6.) If the aviator finds the target and visibility to be particularly favorable and his mission permits him to conduct a destructive shoot he will send C 39 35 98 D followed by the code call for some particular battery, when the battery called will proceed to fire on the target for destruction, the ranging being performed by the aviator.

(7.) In all cases, except for destruction, batteries will open fire on the target designated by the aviator fifteen (15) minutes after receiving the zone call.

The counter-battery organization here suggested is based upon the assumption that our army will be organized as it was in the A. E. F. Experience in the war has shown us that such army organization is not altogether ideal, particularly so far as Artillery is concerned, and a re-organization, eliminating Army Artillery from the field of activity and merely maintaining it as a reserve to become Corps Artillery as required would do much towards simplifying the counter-battery coordination problem.

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the page just ahead of the frontispiece.

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The Journal can be your forge to weld the post-war outlook of the Corps.

USE IT!

German Railroad Artillery on the Belgian Coast

By Major Donald Armstrong, C. A.

Subsequent to a study, made in December, 1918, of the coast defense system installed by the Germans from the vicinity of Ostend to a point close to the border of Holland, Major A. Norton, C. A. C., and the writer of the present article submitted a joint report on the results of the examination. Due to limited time and incomplete data obtained from the only available source of information, a captured German map, certain batteries were not discovered until after the report had been submitted. These batteries, the most important of which were two additional railroad batteries, were discovered in studying aeroplane photographs, and have made it necessary to revise the report with the supplemental information, verified by the present writer during a second visit to the Belgian coast.

One of the most interesting phases in the study of this coast defense system was the employment of railroad artillery. The purpose of this paper is to answer the following questions:

1. To what extent was railroad artillery used?
2. What was its relation to the fixed defenses?
3. When were these batteries installed, as compared with dates of construction of other batteries?
4. What type of battery and emplacement was used?
5. What type of gun and carriage was used?

The Belgian coast defense system included for its major caliber armament five 38-cm. guns, four 30.5 cm. guns and twenty 28-cm. guns, omitting from this count the four old guns of Battery Hindenburg and the 28-cm. mortars of Battery Groden, which were of a very old model and had a very limited range. Of these twenty high power, long range 28-cm. guns, sixteen were on railroad mounts in the four railroad batteries which, from right to left, were:

Battery Het Zoute,
" Hessen (Donkerlock),
" Hanover (de Hann),
" Preussen (Turkijen).

It is thus seen that a large proportion of the heavy armament was of the railroad type, sixteen out of twenty-nine guns.

In answer to the second question, the four railroad batteries located between Ostend and the Dutch border were at fairly equal intervals, the distance between them being eleven, eight and seven kilometers, commencing with Battery Het Zoute. Their fire, the maximum range being 27,500 meters, covered the area from the eastern border to some space behind the Western front. Like the other major caliber batteries, all the railroad batteries were located at considerable distances from the shore line and from the other batteries, excepting the anti-aircraft pieces for the immediate defense of the battery in question. For instance, Battery Hessen is located about 2500 yards from the shore line and Battery Preussen about 500 yards inland. It is not believed that the railroad positions were installed with a view to providing emplacements to be occupied only in case of threatened attack. When constructed, these batteries were, of course, fixed positions, although the guns could be removed in a space of time less than one hour, and when it became necessary to evacuate the coast, these guns were the only ones saved.

The answer to the third question concerning the dates of construction is deemed of importance as showing the changes in the German practice of coast defense as a result of their war experience. Their first heavy battery, Battery Von Tirpitz of four 28-cm. guns, was completed in 1915 and is a typical emplacement with concrete and sand parapet, the guns disposed at intervals of 45 meters. Battery Deutschland, four 38-cm. guns was completed in August, 1917, and after that date the only guns brought in to reenforce the coast defenses were railroad mounts. The following are the dates of completion of the railroad batteries (approximately correct):

Battery Preussen	—September	1917.
" Hessen	—February	1918.
" Het Zoute	—March	1918.
" Hanover	—March	1918.

The novel features of the railroad battery types will appear in the discussion of the next question.

The following points occur to the writer as worthy of emphasis in considering the type of German railway emplacement:

1. Entire absence of parapet protection.
2. Simplicity and cheapness of construction.
3. Speed with which emplacement is constructed.
4. Distance between guns of the same battery and their novel arrangement in the battery.
5. All around fire with no masking of one gun by another.

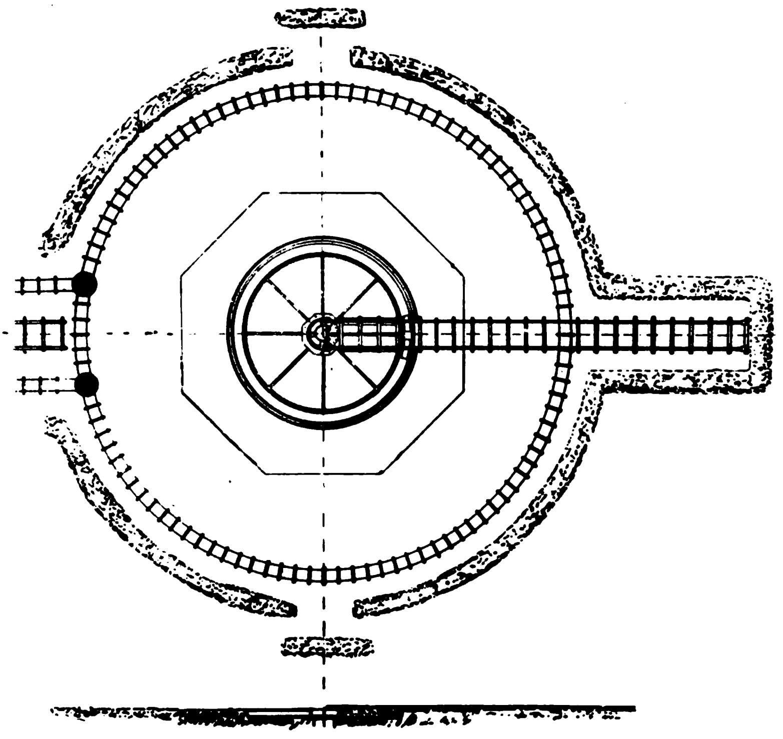

FIG. 1.

The diagram of a railroad gun emplacement reproduced herewith, shows it to be a simple octagonal concrete platform with a circular steel base fixed in the concrete in the center, and provided with a circular traversing path. Reference to the diagram will make clear the disposition, showing the concentric narrow gauge track for ammunition supply, and the short piece of track extending to the front to provide space for the forward bogie when withdrawn. An artificial hedge surrounds the gun and carriage to conceal it from view. It will be noted that no parapet is provided. The ammunition supply was apparently kept in very thin-walled concrete shacks, the floors of which were on a level with the floors of freight cars bringing in the projectiles and powder. From these shacks the ammunition was carried on narrow gauge cars to a position in rear of the gun, whatever the azimuth of fire. The only heavy concrete structure found in the vicinity of these guns was a strong shelter located in the center of each battery, which was undoubtedly the P. C.

The simplicity and cheapness of this emplacement is obvious. It can be completed within seven weeks' time, as compared, for example, with a year and a half necessary to build Battery Von Tirpitz whose power was no greater than that of one of these batteries.

With the exception of Battery Hessen, all the railroad batteries were of the same design as regards relative location of the guns. The guns were disposed in a regular manner, but were located on the corners of a parellelogram. This prevented enfilading fire to a great extent and the masking by one gun of another. The arrangement is made clear by the sketch reproduced in the July number of the JOURNAL illustrating the Report on Coast Defenses Constructed by the Germans on the Belgian Coast.

In answering the last question, it is, of course, impossible to reproduce photographs of the guns in position, as they were all withdrawn. However, it has been possible to obtain excellent photographs showing the type of gun and carriage. The German artillery included in its armament three different pieces firing from the type of carriage belonging to this emplacement, viz., 21-cm. and 28-cm. guns and a 24-cm. howitzer. From conversation with the inhabitants of the vicinity of these batteries, there seems to be no doubt that the pieces in all these emplacements were the 28-cm. gun, and it has been so assumed in describing the installation. Photographs of the two other types, which were among the German guns turned over to the U. S. at the armistice, are included to show the German stadardization of railroad mounts for different calibers.

The German 28-cm. gun on Railway mount (40 calibers 28-cm. SKL 40) was described in the July, 1919, issue of the Journal, on pages 29 et seq.

The German installation on the Belgium coast represents of rail in track A of the main line separated by one length of rail.

5. To construct the switch or "Take off" the procedure would be as follows, with all work going on simultaneously:

(a) Lay tracks C and D in the desired directions starting four inches from track A of the main line.

(b) Install "Take off" and switch ties midway between existing ties.

(c) Install tracks E and X on a curve of 13° 26′ which commences at the end of the straight ten foot piece and ends at the wide end of the switch point. When sufficient trackage along C-D has been constructed to allow all desired cars to be placed on this track and still be clear of the main line, obtain the right of way on the main track for one-half hour. (Part of this time will be utilized for switching purposes and would be required even for a permanent switch.) A working party of ten men at each of the rail ends H and I is considered in estimating the time required as one-half hour.

6. The moment the track was turned over to the Artillery, the spikes on the northern half of track lengths H and I of track A would be pulled. Fishplates 1 and 2 would be removed. The North end of track length I would be sprung over until it coincided with track C and temporarily spiked in position. The North end of track length H would be sprung to the west about twelve inches and temporarily spiked there. The short length G would be placed to connect track D to the length E and it would be spiked in place. Switch point F would be swung in against the rail B and spiked in place. The track is then ready for switching the train which should proceed at a rate of about two miles per hour over the switch.

7. Immediately after the last car has passed into the access track all temporary spikes would be withdrawn, the piece G removed, the switch point swung back to its original position, the rails of track A allowed to spring back to their normal positions, all permanent spikes replaced and the track re-opened for through service on the main line.

8. The arrangement of the switch as shown on the diagram provides a thirteen degree and twenty-six minutes curve or radius of curvature of 427.45 feet. A switch point with switch angles of 1°44′ 11″ is required and the angle which the length G makes with the track A is 8°12′ 16″.

9. This method of take off is applicable to every type of railway gun from the sixteen-inch howitzer to the seven- and

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PAID-UP SUBSCRIPTIONS

An Emergency Switch for Railway Artillery

By Major John K. Meneely, C. A.

1. Railway artillery has, since its conception, been greatly limited in its possiblities due to its inability to occupy positions quickly close to standard gauge existing tracking. This inability to occupy such positions was the result of the impossibility of stopping traffic on a line during the time required to install a switch. Imagine the confusion and delays which would have resulted if a single track road, from a principal salient to its base was cut off for a period of eight hours. Such delay could not have been allowed, hence excellent railway artillery positions were abandoned time and again during the recent war.

2. The French endeavored to surmount this difficulty, as well as to modify an epi mount to a limited traverse mount, by equipping 19 c.m. guns with a central pintle which fitted into a pintle-support that rested on the railroad ties. The weight of the gun was transferred from the tracks to the pintle and while so supported the gun was turned 90 degrees to a position normal to the track and then run on temporary tracks to its platform. It was not necessary to cut the main line tracks at all. This was an excellent scheme but could scarcely be accomplished in less than four hours.

3. It is essential then, that our present railway artillery be provided with a suitable means of leaving any main line track at any place, without actually cutting the tracks, in an absolute minimum of time. Such a means would consist of a temporary switch as is shown in Plate I.

4. Referring to Plate I, A-B represents the main line of the trackage system. C-D represents the take off to the gun position or the access track for a series of gun positions. Numbers 1 and 2 represent fish-plates; E represents a standard section of track thirty-three feet long and X a short section twenty-four feet long; G a straight short length, ten feet long to act as a connector between the length X and the rail D; F represents a left handed switch point joined to E; H and I are full lengths

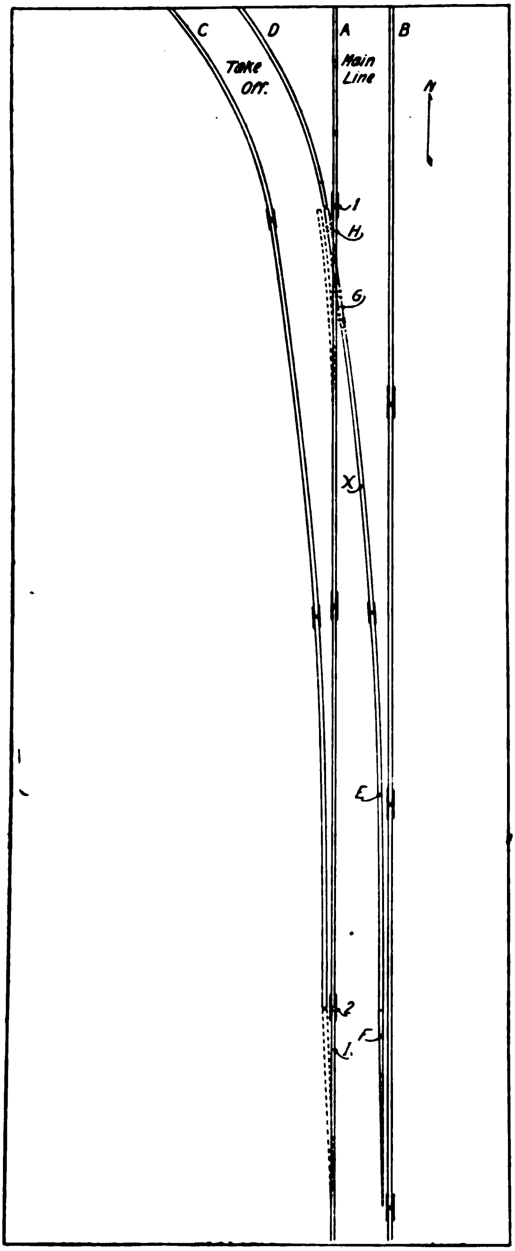

PLATE I.

of rail in track A of the main line separated by one length of rail.

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(a) Lay tracks C and D in the desired directions starting four inches from track A of the main line.

(b) Install "Take off" and switch ties midway between existing ties.

(c) Install tracks E and X on a curve of 13° 26′ which commences at the end of the straight ten foot piece and ends at the wide end of the switch point. When sufficient trackage along C-D has been constructed to allow all desired cars to be placed on this track and still be clear of the main line, obtain the right of way on the main track for one-half hour. (Part of this time will be utilized for switching purposes and would be required even for a permanent switch.) A working party of ten men at each of the rail ends H and I is considered in estimating the time required as one-half hour.

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9. This method of take off is applicable to every type of railway gun from the sixteen-inch howitzer to the seven- and

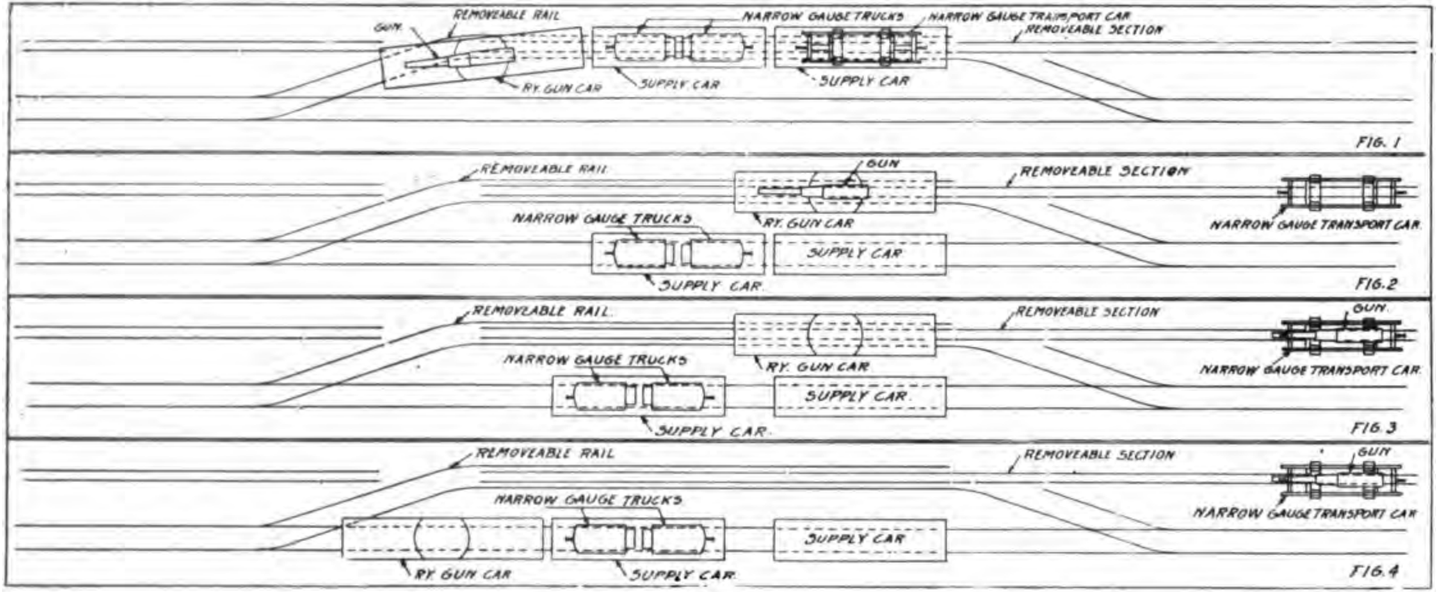
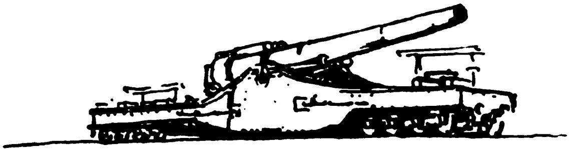

GUN
REMOVEABLE RAIL
RY. GUN CAR
SUPPLY CAR
NARROW GAUGE TRUCKS
SUPPLY CAR
NARROW GAUGE TRANSPORT CAR
REMOVEABLE SECTION
FIG. 1
REMOVEABLE RAIL
NARROW GAUGE TRUCKS
SUPPLY CAR
GUN
RY. GUN CAR
SUPPLY CAR
REMOVEABLE SECTION
NARROW GAUGE TRANSPORT CAR
FIG. 2
REMOVEABLE RAIL
NARROW GAUGE TRUCKS
SUPPLY CAR
RY. GUN CAR
SUPPLY CAR
REMOVEABLE SECTION
GUN
NARROW GAUGE TRANSPORT CAR
FIG. 3
REMOVEABLE RAIL
NARROW GAUGE TRUCKS
RY. GUN CAR
SUPPLY CAR
SUPPLY CAR
REMOVEABLE SECTION
GUN
NARROW GAUGE TRANSPORT CAR
FIG. 4

PLATE II.

eight-inch rifles. There is one point to be borne in mind by the battery commander. After getting his access track started he must use judgment as to the curves he lays on his new access track. A curve to show location has been installed on the drawing. The smaller guns, such as the seven- and eight-inch rifle and twelve-inch mortar will go around almost any curve and surely up to a thirty or forty degree one, while the larger gun cars, particularly those with double trucks at each end, will probably not go around more than a twenty degree curve.

10. The adoption of this method of take off will possibly change the present plan of maneuvering the twelve-inch mortar and seven- and eight-inch rifle from a standard gauge to narrow gauge. Plate II shows that at present it is planned to install two standard switches in the main line, place a siding or turnout and install two or more switches on it. This will, undoubtedly, hold up traffic on at least one track, of the main line, for a minimum of eight hours. With this switch it is believed that the complete train can be removed from the main line to the junction with the narrow gauge system without interrupting the main line for more than one-half hour and with no real alteration to the existing standard gauge line.



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TALK IT UP

Charts for the Calculation of the Effect of Small Changes in the Elements of Fire

By 1st Lieut. P. L. Alger, Ord. Dept.

Abstract

This essay comprises a description of the derivation and uses of a set of charts constructed to show the magnitudes of variations in the range and time of flight of artillery projectiles caused by any change in the muzzle velocity, elevation of fire, or the ballistic coefficient of the projectile. The charts are based upon Ingalls' Ballistic Tables (Artillery Circular M, revised) and their derivation largely follows the discussion given by Col. Ingalls on pages 247-249 of his "Handbook of Problems Exterior Ballistics," (Artillery Circular N). They were prepared at the Sandy Hook Proving Ground during the winter of 1917-1918, largely as a result of the inspection by the author of a quite similar set of charts in a French *Course of Instruction for Artillery Officers*

In general, the use of an extended series of numerical tables is facilitated by having at hand charts or auxiliary tables which present in a clear way the effect on the quantities sought of small changes in the arguments with which the primary tables are entered. Since such charts are primarily designed to show the magnitudes of small *differences* which are to be added to quantities large in comparison, great accuracy is not required in them, but rather compactness. In addition to their usefulness in shortening the labor of computation in some cases and aiding interpolation in others, such auxiliary charts greatly promote a clear understanding of the primary tables by giving a view of the entire field from a new viewpoint and by showing the relative effects of changes in the arguments under different initial conditions.

In particular, charts of the nature described have an especially useful field in connection with ballistic tables. In the study of exterior ballistics, questions of dispersion, involving a knowledge of the effects of small variations in the conditions of fire, are very important. By suitable charts calculated from the data of the primary tables, a clear view of the effects of any changes in the initial elements of fire upon the final elements, covering the entire range of conditions met with in practice may readily be given. The charts to be described have been made principally with the intention of facilitating the study of dispersion questions.

As examples of their field of usefulness, consider the following instances: It may be seen by reference to the chart for the effect on range of a change in the ballistic coefficient, that a change of 10% in air density never causes a change of more than 6% in range and that for long range firing (high velocity guns at elevations of 20 to 50°)* it may be assumed as a general rule that 10% change in air density causes about 5% change in range. Again, a comparison of the charts for the effects on range of changes in C and in V shows that, whereas at elevations below 10° uniformity of muzzle velocity is far more important than constancy of ballistic coefficient (stability, absence of fringing of the bands, etc.) in securing accuracy of fire, the reverse is true at elevations of 20 to 50°. Still again, an inspection of the charts for changes in the time of flight show that the effects on the time of variations in the initial elements are only about half as great as the effects on the range. In consequence of this fact, it is extremely difficult to secure reliable data on dispersion questions by measuring the time of flight, even if the greatest accuracy is sought for in time measurements.

Attempts were actually made at Sandy Hook to determine the dispersions in muzzle velocity and ballistic coefficient that would account for observed variations in range and time of flight, by setting up and solving simultaneous equations of the forms:—

$$\frac{dX}{X} = l\frac{dv}{10} + m\frac{dc}{c} + n\frac{d\varphi}{X}$$

$$\frac{dT}{T} = \lambda\frac{dv}{10} + \mu\frac{dc}{c} + \eta d\varphi$$

Here dX and dT were equal to the average dispersions in range and time of flight found by actual observation; the coefficients of variation 1, m, n, λ, μ, and η were taken from the charts at points corresponding to the initial conditions, dφ was assumed at a reasonable value or as equal to 0, and dV and dC were found by solution of the equations. The values of dV and dC thus found were unreasonable in most cases, however, and were not in accord with separate measurements of velocity variations, nor could they be made reasonable by any assumption as to the values of the dispersion in jump. The failure to obtain satisfactory results was attributed to inaccuracy in the data, to an insufficient number of rounds being used, and to the existence of variations in the flight of projectiles which could not be attributed to changes in V, C or φ alone.

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*The statements made in this paragraph in reference to the elevation do not appear directly from the charts, since the independent variable used is Z, not φ. They follow, however, from the fact that Z increases with φ and in general a large value of Z means a large value of φ.

At the present time, when the very large dispersions, which were largely the cause of the initiation of the investigations described, have been discovered to be due to fringing of the rotating bands, and have been eliminated, and when much more extensive and reliable data are at hand at the Proving Ground, it would be very appropriate to undertake these investigations anew in the hope of throwing further light on the causes of dispersion.

The charts which have been made only show the effects of changes in the initial elements and two of the final elements, the range and the time of flight. These two elements only were treated because they alone can readily be measured experimentally. However, the methods used could readily be extended to cover the preparation of similar charts for changes in the maximum ordinate, angle of fall, etc. Before going further into the practical use of the charts, a description of their derivation will be given.

The Siacci theory was followed in deriving these charts for the reasons that it was very suitable for the purpose and that the methods and data required were at hand in Col. Ingalls' works. The Siacci theory is now considered obsolete, and is being abandoned in favor of the so called short arc or numerical integration methods; this for the reasons that the former method is theoretically inexact (especially so at high elevations of fire), while it affords no means of accuractely taking into account the variations in air density, wind, and temperature aloft or the precessional motion of projectiles.* However, the Siacci method presents several advantages for the purpose of preparing these charts, and in view of the only approxim results desired, its inaccuracy is not so serious a disadvant as to outweigh the other considerations at the present st of the game.

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*Editor's Note: Recent investigations, comparing the practical results obtained by the short arc method with the Siacci theory, indicates the propriety of witholding complete acceptance of this conclusion.

Under the Siacci theory, the ratios of the range and m mum ordinate in vacuum to those in air, and other chara istic properties of the trajectory are fixed by a knowled the muzzle velocity, V, and the ratio Z, of the range i to the ballistic coefficient. Whatever the values of φ a are, these characteristic properties are fixed by V ar In this way, it is made possible to give in a set of *double* tables all the information necessary to find all the rem elements of any trajectory when any three are known. other, and more accurate theories, no exact propertie trajectory are common, and the results of any firing can accurately found by the use of a set of *triple entry* unless laborious computation is to be resorted to eac Now a set of triple entry tables can not readily be repr in chart form, as the three entry variables plus the sought make four variables to be shown on a single and the representation of more than three variables chart is impracticable.

The values of certain ratios between corresponding in the initial and final elements of a trajectory are a by a knowledge of V and Z, only, under the Siacci while under more accurate theories they depend up variables. Consequently, the construction of the ch described is only practicable under the Siacci or an e theory, unless average curves or separate curves ap different regions are found by extended short arc com Such short arc computations as have been made, have shown good agreement with the values deri these charts, and it is therefore considered that fo poses intended the charts are quite sufficiently accu further reference to their reliability will be made, t

In deriving the equations on which the charts an understanding of Siacci's theory is essential. I ing the derivation here, the explanation of the usu the theory will be reduced to a minimum, as the usu will be conformed to, as complete information th readily be secured by reference to standard work tics, and as, theoretically at least, the audience to paper is addressed is already familar with the sub

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The fundamental equations of exterior ballistics a

$$-\frac{dv}{dt} = \frac{f(v)}{C} + g\sin\theta$$

and
$$\frac{vd\theta}{dt} = -g\cos\theta$$

obtained by resolving the forces acting on the project the tangent and normal to the trajectory, respectiv the Siacci theory, it is necessary to represent the air re f (v), by an exponential function. Hereafter, f (v) represented by $A_0 v^n$, it being understood that A_0 anc different values over different ranges of values of v.

Making this substitution for f(v), eliminating dt sion, and reducing, we have:

$$\sec^2\theta d\theta = \frac{gC}{A_0}\cos^{n-1}\theta\frac{d(v\cos\theta)}{(v\cos\theta)^{n+1}}$$

By eliminating dθ instead of dt, we have

$$dt = -\frac{C}{A_0}\cos^{n-1}\theta\frac{d(v\cos\theta)}{(v\cos\theta)^n}$$

Multiplying (4) by v cos θ, we obtain

$$dx = v\cos\theta dt = -\frac{C}{A_0}\cos^{n-1}\theta\frac{d(v\cos\theta)}{(v\cos\theta)^{n-1}}$$

Following the compact form of explanation given Ingalls in Artillery Circular N, page 241, it is to be no these last three equations have first members that are integrable and second members that would be so we for the presence of the variable factor $\cos\theta^{n-1}$. The of Siacci's method consists in his replacing this variab by the constant factor $\cos^{n-2}\varphi$ which is nearly equal to approximation is inaccurate except for direct fire. and tially compensated for by the insertion of an integratin β into the equations. Since β is usually absorbed value of C, and since it complicates the explanation being essential, it will be omitted in the discussion. the substitution for $\cos^{n-1}\theta$ indicated, equations (3), (5) becomes:-

$$\sec^2\theta d\theta = \frac{gC}{A_0\cos^2\varphi}\frac{du}{u^{n+1}}$$

preparing these charts, and in view of the only approximate results desired, its inaccuracy is not so serious a disadvantage as to outweigh the other considerations at the present stage of the game.

Under the Siacci theory, the ratios of the range and maximum ordinate in vacuum to those in air, and other characteristic properties of the trajectory are fixed by a knowledge of the muzzle velocity, V, and the ratio Z, of the range in air to the ballistic coefficient. Whatever the values of φ and C are, these characteristic properties are fixed by V and Z. In this way, it is made possible to give in a set of *double entry* tables all the information necessary to find all the remaining elements of any trajectory when any three are known. Under other, and more accurate theories, no exact properties of a trajectory are common, and the results of any firing can only be accurately found by the use of a set of *triple entry* tables, unless laborious computation is to be resorted to each time. Now a set of triple entry tables can not readily be represented in chart form, as the three entry variables plus the variable sought make four variables to be shown on a single chart, and the representation of more than three variables on one chart is impracticable.

The values of certain ratios between corresponding changes in the initial and final elements of a trajectory are also fixed by a knowledge of V and Z, only, under the Siacci theory, while under more accurate theories they depend upon three variables. Consequently, the construction of the charts here described is only practicable under the Siacci or an equivalent theory, unless average curves or separate curves applying to different regions are found by extended short arc computations. Such short arc computations as have been made, however, have shown good agreement with the values derived from these charts, and it is therefore considered that for the purposes intended the charts are quite sufficiently accurate. No further reference to their reliability will be made, therefore.

In deriving the equations on which the charts are based, an understanding of Siacci's theory is essential. In performing the derivation here, the explanation of the usual parts of the theory will be reduced to a minimum, as the usual notation will be conformed to, as complete information thereon may readily be secured by reference to standard works on ballistics, and as, theoretically at least, the audience to whom the paper is addressed is already familar with the subject.

The fundamental equations of exterior ballistics are:

$$-\frac{dv}{dt} = \frac{f(v)}{C} + g \sin \theta \qquad (1)$$

and

$$\frac{v d\theta}{dt} = -g \cos \theta \qquad (2)$$

obtained by resolving the forces acting on the projectile along the tangent and normal to the trajectory, respectively. In the Siacci theory, it is necessary to represent the air resistance, f (v), by an exponential function. Hereafter, f (v) will be represented by $A_0 v^n$, it being understood that A_0 and n have different values over different ranges of values of v.

Making this substitution for f(v), eliminating dt by division, and reducing, we have:

$$\sec^2\theta d\theta = \frac{gC}{A_0} \cos^{n-1}\theta \frac{d(v \cos \theta)}{(v \cos \theta)^{n+1}} \qquad (3)$$

By eliminating dθ instead of dt, we have

$$dt = -\frac{C}{A_0} \cos^{n-1} \theta \frac{d(v \cos \theta)}{(v \cos \theta)^n} \qquad (4)$$

Multiplying (4) by v cos θ, we obtain

$$dx = v \cos \theta dt = -\frac{C}{A_0} \cos^{n-1} \theta \frac{d(v \cos \theta)}{(v \cos \theta)^{n-1}} \qquad (5)$$

Following the compact form of explanation given by Col. Ingalls in Artillery Circular N, page 241, it is to be noted that these last three equations have first members that are exactly integrable and second members that would be so were it not for the presence of the variable factor $\cos\theta^{n-1}$. The essence of Siacci's method consists in his replacing this variable factor by the constant factor $\cos^{n-2}\varphi$which is nearly equal to it. This approximation is inaccurate except for direct fire, and is partially compensated for by the insertion of an integrating factor β into the equations. Since β is usually absorbed into the value of C, and since it complicates the explanation without being essential, it will be omitted in the discussion. Making the substitution for $\cos^{n-1}\theta$ indicated, equations (3), (4) and (5) becomes:-

$$\sec^2\theta d\theta = \frac{gC}{A_0 \cos^2\varphi} \frac{du}{u^{n+1}} \qquad (6)$$

$$dt = -\frac{C}{A_0 \cos\varphi}\frac{du}{u^n} \tag{7}$$

$$dx = -\frac{C}{A_0}\frac{du}{u^{n-1}} \tag{8}$$

where v cosΘ secφ has been replaced by u for simplicity. U is called the *pseudo velocity.*

Integrating these equations over the entire trajectory, we have:

$$-\tan\omega = \tan\varphi - \frac{C}{2}\sec^2\varphi(I_u - I_v) \tag{9}$$

$$T = C\sec\varphi\,(T_u - T_v) \tag{10}$$

$$X = C\,(S_u - S_v) \tag{11}$$

where the functions of u above obtained on integration have been replaced for convenience by the symbols I_u, T_u, and S_u. Replacing tanΘ in the integral of (6) by dy/dx, and integrating over the entire trajectory, we obtain:

$$\sin 2\varphi = C\left[\frac{A_u - A_v}{S_u - S_v} - I_v\right] \tag{12}$$

in which A_u has replaced $-\int^u \frac{I_u du}{A_0 U^{n-1}}$;obtained in integrating.

The four functions S_u, T_u, I_u, and A_u, are called the primary functions, and they are tabulated for each value of u by Col. Ingalls in Table I of his ballistic tables which are published in Artillery Circular M. Knowledge of these functions and of any three elements of a trajectory enables all the other elements to be calculated by the formulas (9) to (12) though the processes are laborious and involve trial and error methods in some cases.

Braccialini, however, suggested the use of secondary functions for particular muzzle velocities to replace the differences of primary functions I_u, I_v, T_u, T_v, etc. and Col. Ingalls computed tables on this basis which greatly facilitate computation.

Considering only the point of fall, by making the following substitutions in equations (9) to (12) much simpler forms result.

$$\text{Let } A = \frac{A_u - A_v}{S_u - S_v} - I_v \tag{13}$$

$$B = I_u - \frac{A_u - A_v}{S_u - S_v} \tag{14}$$

$$B^1 = \frac{B}{A}, \text{ (also designated } \frac{1}{L}) \tag{15}$$

$$Z = S_u - S_v \tag{16}$$

$$T^1 = T_u - T_v \tag{17}$$

Putting (16) in (11), (17) in (10), (13) in (12), and combining (12), (13), and (14) with (9), we obtain:-

$$X = CZ \tag{18}$$

$$T = CT^1 \sec \varphi \tag{19}$$

$$\sin 2\varphi = AC \tag{20}$$

$$\tan \omega = B^1 \tan \varphi \tag{21}$$

Corresponding values of Z, T, A and B^1 are tabulated for a series of values of V in Ingalls' Table II, Artillery Circular M.

Having now obtained the principal equations of exterior ballistics under the Siacci theory, we are in a position to determine the effects of small variations in the initial elements of fire. Still following the methods of Col. Ingalls, the problem of finding the effects of these variations upon the range requires as a first step the determination of the complete differential of X when C,V, and φ vary simultaneously. Consider equations (11) and (12). They determine X and φ as functions of C, V and u. By differentiating these equations, therefore, and replacing the differential of u in the former by its equal in terms of those of C, V, and φ the required step may be taken.

In this process the derivatives of the primary functions will occur, and the following expressions for them will therefore be found useful.

$$\frac{dS_u}{du} = -\frac{1}{A_0 u^{n-1}} \tag{22}$$

$$\frac{dA_u}{du} = -\frac{I_u}{A_0 u^{n-1}} \tag{23}$$

$$\frac{dI_u}{du} = -\frac{2g}{A_0 u^{n+1}} \tag{24}$$

$$\frac{dT_u}{du} = -\frac{1}{A_0 u^{n}} \tag{25}$$

The actual work of finding the equation sought by means of the material so far collected requires only the simplest principles of calculus. However, as the successive equations found in the process are rather cumbersome to write down in precise notation, and would prove unprofitable reading to most, we will simply state the successive steps of the process and then set down the result.

It is convenient to take V, C, and X as the 3 independent variables. With this understanding, carrying through the following steps will lead to the desired result:

(a) Differentiate (11) with respect to C, V, and X in turn, obtaining the three partial derivatives of u.

(b) Differentiate (12) with respect to C, V, and X, and substitute the results of (a) in the equations found, thus obtaining the three partial derivatives of φ.

(c) Add the 3 partial derivatives of φ to obtain its total differential or

$$d\ (\sin 2\varphi) = A(1-B^1)dC + C\left(\frac{\delta A}{\delta V}\right)_{c,x} dV + \frac{A\,B^1\,C}{X}\,dX \quad (26)$$

which rearranged, becomes

$$\frac{dX}{X} = \left(1 - \frac{1}{B^1}\right)\frac{dC}{C} - \frac{1}{AB^1}\left(\frac{dA}{\delta V}\right)_{c,x} dV + \frac{2\cos 2\varphi}{A.B.^1C}\,d\varphi \quad (27)$$

This equation is merely an abbreviated and precise statement of the effects on the range of any small variations in the elements of fire. That is, it may be expressed in words as follows:

If a projectile of ballistic coefficient C is fired with a velocity V and an elevation φ to a range X, *then* a similar projectile with a ballistic coefficient C+dC, fired with a velocity V+dV at an elevation φ+dφ, will attain a range X+dX; where dX is equal to the sum of the products of the percent change in C, $\frac{dC}{C}$, the change in velocity, dV, and the change in φ,dφ, by the respective numerical coefficients

$$\left(1 - \frac{1}{B^1}\right),\ -\frac{1}{AB^1}\left(\frac{\delta A}{\delta V}\right)_{c,x},\ \text{and}\ \frac{2\ \cos\ 2\varphi}{A\ B^1\ C}.$$

The reason that the coefficient of V is expressed as a partial derivative is that this partial derivative is a function of the air resistance which has never been calculated and presented in tabular form. It so happens that the coefficients of dC and dφ are expressible in terms of secondary functions which are conveniently recorded in Ingalls' Ballistic Tables, while the other coefficient is not.

Equation (27) is identical with Ingalls' formula (57^1) on page 249 of Artillery Circular N and with equation (28) on page XIII of Artillery Circular M revised. Charts I, II, and III, which form the subject of this article, are merely graphical presentations of the values of the three coefficients in equation (27) for any conditions of fire.

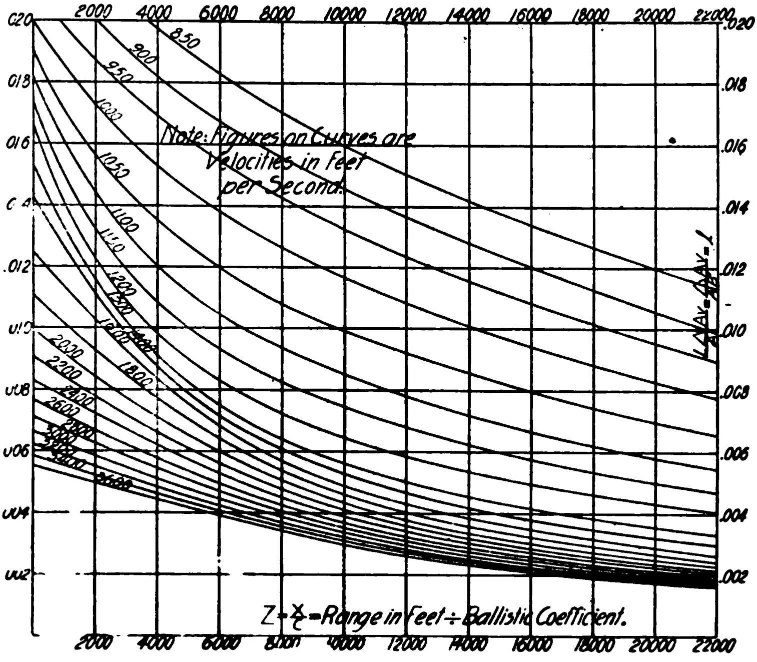

Chart I. Effect of Velocity on Range

Chart I shows the effect on range of a 10 f/s. change in V, C and φ remaining constant. It was prepared by computing the quantity $\frac{-10}{AB^1}\left(\frac{\delta A}{\delta V}\right)_{C,X}$ called l for convenience, for a series of values of V and Z with the aid of Ingalls' Table II, plotting the values against Z, and drawing curves through points of equal V. The quantity l is derived from equation (27) by making dC = o, dV = 10 f/s. and dφ = o. Since $\left(\frac{\delta A}{\delta V}\right)$

C,X is not a tabulated quantity it was computed by taking differences between the values of A given in table II for different values of V and equal values of Z and dividing these differences by the increments in V corresponding. Values of A for the same Z are differenced, because $\left(\frac{\delta A}{\delta V}\right)_{C,X}$ is the partial differential of A with respect to V when C and X are constant, and if C and X are constant, so also is Z, which is equal to $\frac{X}{C}$.

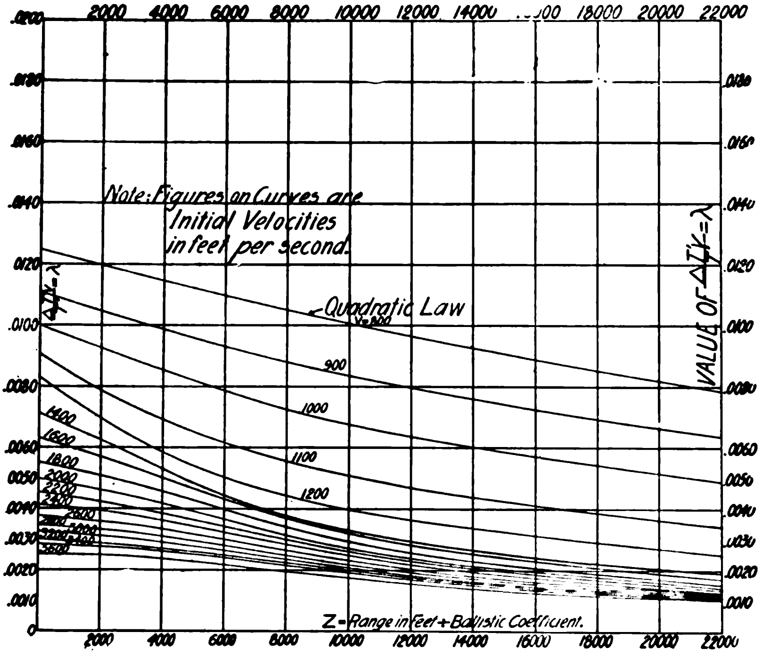

CHART II. EFFECT OF C ON RANGE

It may be noted that this process of finding the coefficient of dV in equation (27) by taking differences out of existing tables is one that could have been followed for all the coefficients, thus avoiding all the labor involved in deriving equation (27). But this process is much less accurate than that of computing the coefficients by formulas, since the magnitudes of the tabular differences are small and they are consequently erratic. Also such a process gives no clear understanding of the causes for the variations in the coefficients. For these reasons, computation was preferred to the difference method and was used in all cases except that of l. To be sure, $\left(\frac{\delta A}{\delta V}\right)_{C,X}$ could have been computed from the original exponential air resistance formulas, but this was considered to be proceeding too far to the other extreme of excessive computational labor.

Chart II presents the effect on range of a change of 1% in the ballistic coefficient, C, while V and φ remain constant. It was prepared by computing values of $\left(1-\frac{1}{B^1}\right)$, called m for convenience, for different values of V and Z with the aid of Ingalls' Tables, plotting these values against Z and drawing curves through all points of equal V. The quantity m is derived from equation (27) by making dV and $d\varphi = o$ therein.

In a similar way, Chart III was prepared to show the effect on range of a change in the angle of departure, φ, while V and C stay constant. In this case, however, the coefficient of $d\varphi$ in equation (27) does not depend only on Z and V. Consequently, it was not possible to represent the % change in range occurring directly, and two changes in the procedure were forced. Making dC and dV = o in equation (27) we have:

$$\frac{dX}{X} = \frac{2\cos 2\varphi}{AB^1C}\, d\varphi \qquad (28)$$

In this equation $d\varphi$ is measured in radians, and, since the use of the degree and minute system is almost universal in recording angles of elevation, it will be advantageous to replace $d\varphi$ by its equal in minutes of arc, $d\varphi'$. There are 3438 minutes in one radian, so utilizing this fact and also equation (18), (28) may be reduced to:

$$\sec\ 2\varphi\ dX = \frac{Z}{1719AB^1}\, d\varphi \qquad (29)$$

The left hand member of this equation can now be charted for an assumed value of $d\varphi$ as a function of V and Z. While Chart III, prepared by this process, is not so convenient as charts I and II, since it requires the multiplication of the quantity read off it by cos 2φ before the value of dX is found, and since it even then gives only the absolute magnitude of the range change instead of the percentage change, still it affords a far readier process of finding dX than the usual method of using equations (18) and (20) conjointly in connection with

Table II. A brief table of values of cos 2φ is given on the chart to facilitate the computation. It was thought most convenient to give dX in yards, rather than feet, so that the quantity actually charted was $n \sec 2\varphi = \frac{Z}{5157AB^1}$, obtained by dividing the coefficient of $d\varphi^1$ in equation (29) by 3.

The purposes, character, and manner of derivation of Charts I, II and III which facilitate the calculation of range changes have now been described. It remains to briefly show the derivation of the remaining charts, which facilitate the calculation of changes in the time of flight, and to illustrate the use of the charts by examples. Before proceeding to these points, however, it is desirable to call attention to the meaning of the ballistic coefficient, C, as used in this article. In its true meaning, and as it is actually used in the short arc methods, the ballistic coefficient is a measure of the ability of a projectile to retain its velocity in still air of normal density and temperature. In the present case, however, the meaning of C usual in the Siacci method is taken, which is simply that coefficient which will give the correct normal range X, in con-

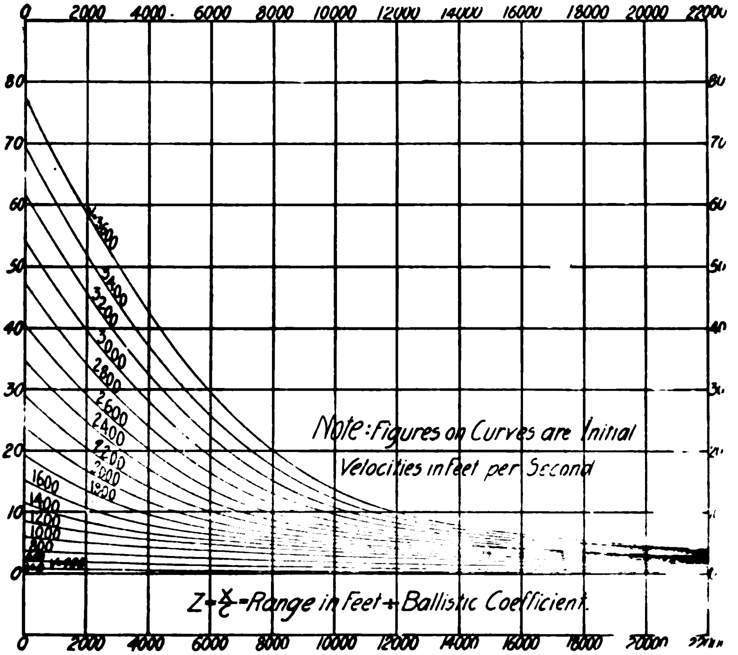

CHART III. EFFECT OF ELEVATION ON RANGE

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junction with the true values of φ and V when entry is made into Table II. To distinguish the two definitions, the former more precise value is usually designated by C_0. C is equal to C_0 times an altitute factor, an integrating factor, and such other factors as may be required to make an incomplete theory agree with experiment.

When these facts are understood, it will be perceived that C is not really independent of V, nor of φ, and that the true effect of a change in V is not obtainable from Chart I alone, but must be supplemented by the addition from Chart II of the change in range due to that variation in C which ensues in consequence of the change in V. A similar statement holds for φ. Theoretically, C_0 is invariant with φ and V, and hence has not the disadvantage of C, but practically, on account of our inexact laws of air resistance, C_0 also changes with both φ and V. At the present stage of the science, the variations required in C_0 to secure agreement with experiments are somewhat less than those in C, and it is expected that the advantage of constancy for a given projectile will pertain to C_0 in greater degree as our knowledge progresses. Ordinarily and especially for the approximate purposes for which these charts are designed, these variations in C and C_0 may be neglected, but they must be taken into account in the construction of range tables.

Taking up now the derivation of the charts to present the effects of variations in φ,V, and C on the time of flight we will, as before, simply outline the method of deriving the equation desired, and then state the result.

Here it is convenient to take C, V, and φ as the independent variables. On this basis, (10) may be differentiated with respect to C, V, and φ in turn, the results may be simplified by the equations previously found, and the resulting three equations may be added to give the total differential of T, or

$$\frac{dT}{T} = \left(\frac{1-Z}{uB^1T^1}\right)\frac{dC}{C} + \frac{1}{T^1}\left(\frac{\delta T^1}{\delta V}\right)_{c,\varphi} dv + \tan\varphi\left(1 - \frac{Z}{uB^1T^1}\right)d\varphi + \frac{Z\cot\varphi}{uB^1T^1}\,d\varphi \qquad (30)$$

This equation does for the time of flight what (27) does for the range. A comparison of corresponding coefficients in the two equations shows the relative variations in T and X produced by equal changes in the elements of fire, C, V, or φ.

The coefficient of dV in this case also happens to be non-representable in terms of tabular functions, except as a partial derivative.

Chart IV was constructed from the equation found by making dC and $d\varphi = 0$ and $dV = 10$ f/s in (30). $\frac{10}{T^1}\left(\frac{\delta T'}{\delta V}\right)_{C,\varphi}$ called X for convenience, was computed with the aid of Table II for a series of values of V and Z, and plotted against Z, curves being then drawn through all points of equal V.

Similarly, by making dV and $d\varphi = o$, and $dC = .01$ in (30), the basis of Chart V is found.

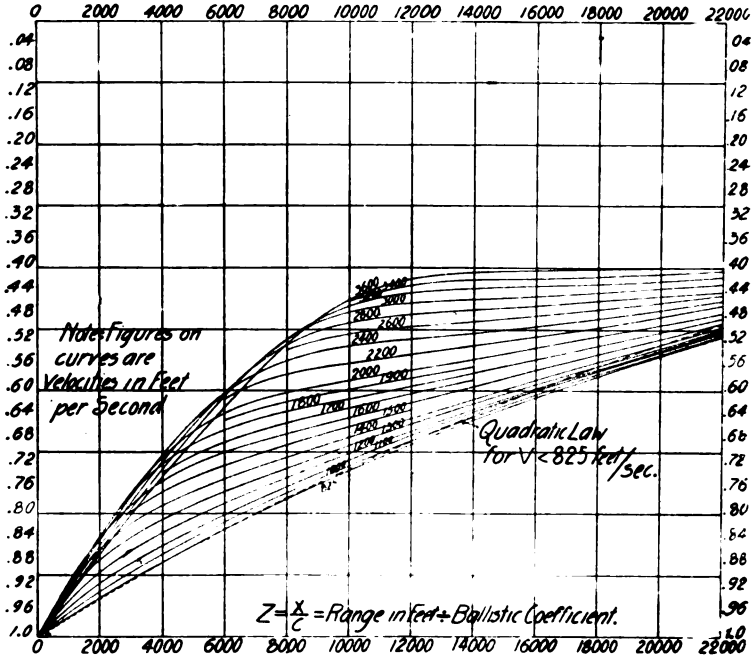

Chart IV. Effect of Velocity on Time

Values of $\left(1 - \frac{Z}{uB^1T^1}\right)$, called u for convenience, were computed for a series of values of V and Z by means of Table II, and plotted against Z. Finally, as usual, curves were drawn through all points of equal V.

A sixth and last chart to show the effects on T of change in φ was not made because of a difficulty similar to that which arose in the case of Chart III. This difficulty is that the coefficient of $d\varphi$ in equation (30) involves φ as well as V and Z, and that hence it is impossible to represent it on a two dimensional chart like charts I to V. Here, φ occurs in both terms of the coefficient of $d\varphi$ and in different ways, so that it is not feasible to factor the coefficient, chart one part, and leave the other part to be multiplied in later, as was done in the case of Chart III.

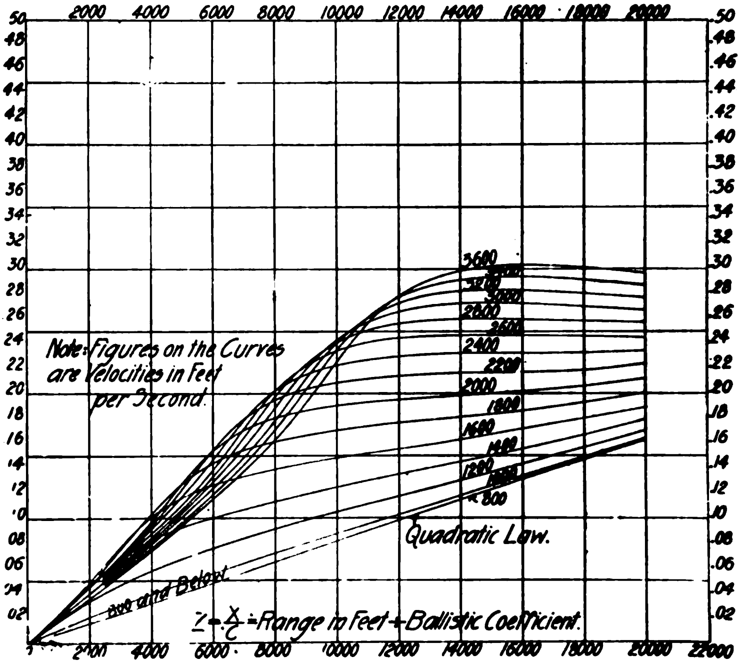

CHART V. EFFECT OF C ON TIME

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Accordingly, in place of a chart, the expression for the coefficient was expressed in terms of quantities derived from other charts and of tan φ as follows:

Putting dV and dC = o, and $\frac{d\varphi^1}{3438} = d\varphi$ in equation (30), there is found:-

$$\frac{dT}{T} = \left[\tan\varphi\left(1 - \frac{Z}{uB^1T^1}\right) + \cot\varphi\frac{Z}{uB^1T^1}\right]\frac{d\varphi^1}{3438} \qquad (31)$$

But, from chart V we have $\mu = \left(1 - \frac{Z}{uB^1T^1}\right)$ Hence, (31) becomes:-

$$\frac{dT}{T} = \left[\mu \tan\varphi + (1-\mu)\cot\right]\varphi\frac{d\varphi^1}{3438} \qquad (32)$$

Since μ, and tan φ are only required to two or three significant figures, equation (32) provides a fairly convenient way of computing dT for a change in φ. For convenience, the coefficient of $d\varphi^1$ in (32) is called η, so that multiplication of T by η will give the change in T resulting from a change of one minute in φ directly.

SUMMARY

There have been derived five charts, by whose aid the changes in range and in time of flight of a projectile caused by any small changes in muzzle velocity, Siacci ballistic coefficient, or angle of departure can conveniently be computed without the use of ballistic tables or any other data except that contained on a slide rule. The charts represent all classes of fire except small arms trajectories for elevations above about 20°, some trench mortar trajectories, and trajectories for muzzle velocities higher than 3600 ft. per second.

The charts are reasonably accurate, that is they may be relied upon to give the coefficients they are supposed to within a few percent, although of course the errors inherent in the Siacci theory, and in the exponential law of air resistance used, exist in addition. In order to improve the accuracy obtainable by the formulas which have been derived, alone, in every case possible advantage was taken of the limiting forms approached by these formulas when the variables approached limits. Thus, when $Z-o$, which corresponds to $C=\infty$ or $X=o$, the ballistic equations reduce to those in vacuo, and this was taken advantage of in computing the ordinates on all the charts at $Z-o$. The irregular distances between curves on charts I and IV are chiefly due to the law of air resistance used.

It should be emphasized that neither the objects sought in the preparation of these charts nor the accuracy attained in them warrant the retention of more than two figures in computation based on them, unless differences are required, when three figures may be retained. In other words it would be unreasonable to use logarithms for such computations. All differential formulas used are assumed to be linear over a considerable range.

For the greatest convenience in use, the formulas for the various charts have been abridged to the following forms:

Chart I.—Effect of Velocity on Range:

$$\frac{dX}{X} = \frac{l dV}{10}, \tag{33}$$

or a 10 f/s. change in muzzle velocity causes 1% change in range, and other changes occur proportionately. The chart gives l directly as a function of V and $\frac{X}{C}$.

Chart II—Effect of Ballistic Coefficient on Range:

$$\frac{dX}{X} = m\frac{dC}{C} \tag{34}$$

or a 1% change in ballistic coefficient causes m% change in range, and other changes occur proportionately. The Chart gives m directly as a function of V and $\frac{X}{C}$.

Chart III.—Effect of Elevation on Range.

$$dX \text{ in yards} = n\, d\varphi^1 \tag{35}$$

or a change of one minute in elevation causes a change of n yards in range, and other changes occur proportionately.

The Chart gives n sec. 2φ directly as a function of V and $\frac{X}{C}$; and a table of values of cos 2φ is provided which enables n to be readily computed. It should be noted that n is positive if $\varphi < 45°$ and negative if $\varphi > 45°$, or in other words, maximum range always occurs at 45° elevation, *if the Siacci C is constant.* From one point of view it may be said that the cause of the occurrence of maximum range above or below 45° is the variable nature of C. If a curve of C against φ is drawn for any projectile, maximum range will occur between the elevation of maximum C and 45°. C is variable largely on account of the altitude and integrating factors contained in it.

Chart IV. Effect of Muzzle Velocity on Time of Flight.

$$\frac{dT}{T} = \frac{\lambda dV}{10} \tag{36}$$

or a change of 10 f/s. in V causes a change of λ% in the duration of flight, and other changes occur proportionately. The Chart gives λ directly as a function of V and $\frac{X}{C}$.

Chart V. Effect of Ballistic Coefficient on Time of Flight.

$$\frac{dT}{T} = \mu\frac{dC}{C} \tag{37}$$

or a change of 1% in ballistic coefficient causes a change of μ% in the duration of flight, and other changes occur proportionately. The chart gives μ directly as a function of V and $\frac{X}{C}$.

Effect of Elevation on Time of Flight.

$$\frac{dT}{T} = \eta^{d\varphi'}, \text{ where} \tag{38}$$

$$\eta = \frac{T}{3438}(\mu\tan\varphi + (1-\mu)\cot\varphi) \tag{39}$$

μ is given by Chart V, while tan φ must be found from a slide rule or tables. In words, a change of one minute in elevation causes a change of η% in the time of flight, and other changes occur proportionately.

The uses of the charts are chiefly in:

(a) Design.—In perceiving the relative advantages of heavy projectiles, high velocities, or high elevations as means of procuring increased range.

(b) Dispersion.—In studying observed dispersions to see what causes could have resulted in them and in what proportion errors may be ascribed to various causes.

(c) Information.—In determining the effect of changes in the elements of fire, as in preparing approximate range tables.

The field of usefulness (b) affords an interesting study in connection with experimental data, but the present methods of measurement of range and time are not sufficiently accurate for all purposes.

If a group of rounds are fired, and the range, X, and time of flight, T, for each round are carefully measured, the mean variations in X and T may be computed. Then, by making the reasonable assumption that errors in range and time due to variations in C, V, and φ are independent, we may set down the following two equations:

$$\Delta X^2 = (\Delta X_c)^2 + (\Delta X_v)^2 + (\Delta X_\varphi)^2$$
$$\Delta T^2 = (\Delta T_c)^2 + (\Delta T_v)^2 + (\Delta T_\varphi)^2$$

In words, the sum of the squares of the (independent) errors due to the three possible causes of variation is equal to the square of the observed error.

ΔX and ΔT being known by experiment, and ΔT_c, ΔX_c etc., being dependent only on ΔC, ΔV and $\Delta\varphi$ and the *approx-*

imate values of the initial elements of fire, we have here two equations in three unknowns, ΔC, ΔV, and $\Delta\varphi$ which are the mean variations in C, V, and φ. If, now, the value of $\Delta\varphi$, say, is known from other data as from successive measurements of jump, or if ΔV is known from the variation in velocity observed in powder tests, we may substitute in the two equations the corresponding values of ΔT_φ and ΔX_φ or ΔT_v and ΔX_v, leaving two equations with but two unknowns. Solving these two equations will then give the values of the mean errors in C and in V or φ, which must have occurred in order to obtain the observed results. Thus the cause of dispersion may be justly laid at the door of the powder or the projectile, as the case may be.

The practical difficulty with this scheme of analysis of the errors is that ΔR and ΔT are not experimentally observed with sufficient accuracy under usual conditions. That is, the usual error in measuring the time of flight for any one round is about 0.2 second, which is of the same order of magnitude as the true variation between successive rounds. From the law of addition of independent errors, the true variation in T and X is the square root of the difference of the squares of the mean variation in the observed quantities and the mean error in measurement of any one quantity. Therefore, by always extracting the observational error from the total error in R and T it would be possible to use the foregoing analysis with more success. In any case, it is to be expected that methods of range and time measurement will be improved sufficiently to make the analysis applicable at some later date.

EDITORIAL REVIEWS

THE OLD ORDER CHANGETH

The Army cannot, more than other sorts of people, ignore the signs of confusion, compounded from day to day, which seems to shake and threaten every timber in the structure of organized civilization. Each day the headlines flash some new turmoil, some new clash of race, or class, or interest. Strikes with every urge of reason and unreason compete with riots and thuggery for the first place in the news. Withal, recrimination concerning all the issues of domestic and foreign economy blatantly belie the front of solidarity which we supposed America had welded in the war.

With all this welter of turbulence, it is easy to understand why so many people are troubled, seeing a world distraught and upside down, and, shrinking from the melange which to them is meaningless as to cause and outcome, foresee a cataclysm and the wreck of civilization. Small wonder that they wish there were some safe corner to which they might withdraw and close sight and sense on all the broiling which appears so selfish and perverse, so muddled and futile.

It is not strange that there are those dismayed at the troubleous times, who see the world an awful riddle with no answer, headed for the rocks, even already a total loss with no insurance. It is not to be wondered at that timid spirits seek to turn tail and attain a retreat in the tall timber. If it were indeed true that the disturbance of the world were meaningless and hopeless, without promise of end or solution, the hardy as well as the weak would be justified in leaving a useless struggle to hunt a peaceful seclusion.

But the officer who has learned to be a penetrating student of history need not be dismayed. He may see, as he opens his eyes, the unfolding of a new epoch, the opening of a new chapter of the story of Liberty. Progressively has liberty been enlarged by stirring crises. It is so to speak that the electrical circuit of the world's life, having been fused to carry a limited load of the current of self-expression, has burned out under the heat of this mounting current. After the breakdown, the circuit was re-fused to carry a greater current of human independence. Always has the fuse of restraint proven eventually futile, so that its rating has been successively increased. But, as in an electrical power circuit, every time the fuse blew, the social machinery stopped and was upset until the readjustment could be made. It is one thing to gain independence, and another thing to acquire the poise and responsibility to transform independence into liberty. With this thought before him, Walter Lippman, in "Drift and Mastery", says:

> "What nonsense it is, then, to talk of liberty as if it were a happy-go-lucky breaking of chains. It is with emancipation that real tasks begin, and liberty is a searching challenge, for it takes away the guardianship of the master and the comfort of the priest. The iconoclasts didn't free us. They threw us into the water, and now we have to swim."

The particular crisis in the history of liberty in which we are now involved is caused by the lag in growth of responsibility to meet the accession in economic power and independence of the laboring people of the world. Blind as are some of the processes now under way, they are a stage—and an unavaidoble stage—in our progress toward a better land and a happier world. Every world order was born in travail. The world that we shall live to share will be of a new order, whose birth-pains, begun with the Great War, are not yet completed. The convulsions within our own and other nations, while desolating and fearful, must continue until the spirit of the new order is set free in the acquisition of poise through sobering responsibility by the workers, who are now ruthlessly swinging the economic freedom they have grasped but not yet learned to use.

Not yet have they lost the swollen self-consciousness of power which just now blinds them to the real norm of human relations—the spirit of the square deal, and the willingness to live and let live. The people, the common-people of the world, are carving out a new standard of existence. They will make mistakes for awhile; they will do cruel and senseless things and head into blind alleys, but in the end they will straighten out on the road of common sense.

In spite of the clannish conservatism attributed to him by by the unknowing, the army officer through his daily share in the care for the needs of those entrusted to his charge, is better fitted than members of some of the other educated professions to understand the perplexities and aspirations of people in divers stations—to enter into the thought of Kipling:

Deliver me from every pride—the Middle, High and Low,
  That bars me from a brother's side, whatever state he show.
And purge me from all heresies of thought and speech and pen
  That bid me judge him otherwise than I am judged. *Amen.*
That I may sing of Crowd or King or road-borne company.
  That I may labor in my day, vocation, and degree,

To prove the same in deed and name, and hold unshakenly
  (Where'er I go, whate'er I know, whoe'er my neighbor be)
This single faith in Life and Death and all Eternity:
  "The people, Lord, thy people are good enough for me!"

The Conclusion?—The leadership of the educated man, devoted to the real interest of his fellows, is needed as never before, in *every profession.* The present swaying from one wild extreme to another will be subdued finally and brought to rest by the dominating common sense of those who have the courage to stay in the game, and hold a place undismayed, voicing, as did the dying King Arthur for the distracted Sir Bedivere: "The old order changeth, yielding place to new."

F.F.C.

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PASSING THE BUCK

Of the thousands of temporary officers who served during the emergency, and who have returned to civil occupation, there are undoubtedly a considerable number who carry back as an abiding impression, the belief that "passing the buck" is an interwoven element in regular army executive method, and that one of the perquisites of military rank is the opportunity to "pass the buck." The idea crops out constantly in the press, in magazine articles, and as a humourous or bitter theme in published stories. However the suggestion may appear, in barbless witticism or in stinging criticism, the implication is left that in the Regular Army there is tolerated the spirit of sidestepping responsibility, of avoiding the consequences of possible come-backs on decisions, by turning the formulation of decisions over to subordinates. If there be any general justification for this implication, there is established an arraignment of army standards of honor and ordinary manliness which calls for a sweeping regeneration within the Service. If there be no such general justification, the charge that the army is addicted to "passing the buck" should be vigorously rebutted.

In the first place, let us clear the air by acknowledging the corn when the shoe does pinch. Surely many regular officers can recall specific, if not glaring, instances where, in the past, the buck has been passed to them by their superiors. In the regular army, as in other walks of life, a man is, and has been, expected to stand upon his own feet, to face the decisions that confront him, and to accept the responsibility which falls to his share. Nevertheless, it is doubtless true that certain exhibitions of buck passing have been given by regulars before temporary officers as well as before their associates in the regular service.

It so happens that the officers now on duty with the JOURNAL were both connected during the war with the instruction of temporary officers. From this experience arises a suggestion which may throw light on the whole issue. A proper and well-recognized principle of tactical and administrative control is that of devolution of authority. Even the most unthinking must realize that the functioning of the army is possible only through the delegation of graduated shares of the President's authority through all ranks, down to the veriest lance corporal. But what the unthinking may not realize is that in order to render devolution of authority effective, there must go with it a like devolution of responsibility and initiative. Hence in recent years, the doctrine has been hammered home in the regular army, that initiative must be developed among all ranks and that in order to foster its development, *missions* should be assigned to subordinates, who should not then be interfered with in the execution of the missions. In conformity with this principle it is right, for instance, after the battalion commander's reconnaissance of his new positions, for him to point out to a battery commander the general location of his gun positions, battery P. C., dumps, etc., and then tell the battery commander to go to it. Indeed, unless the major has good reason to doubt the judgment or experience of his captain, it would be wrong for him to prescribe the minutiae of the maneuver, the number and size of the dugouts, the hours of relief, and so on.

But while the principle is right, its operation sometimes caused curious reactions, because the regular officer and the temporary officer lacked a common perspective. For some unknown reason, a great many of the earnest men who came to the training camps entertained the notion that in the new game they were entering, and which for the emergency they were determined to play to the limit, all decision and initiative were autocratic if not arbitrary, were imposed from the top and were subject only to blind execution. Many temporary officers got away from this conception quickly, while others never did wholly. Here was a lack of common ground in understanding. Many regulars never did sense that officers serving with them were perplexed by lack of detail in orders, when these same subordinates, in their civilian professions, were men accustomed to work out their own or others' ideas, with untrammelled initiative. Conversely, the temporary officer, led by his preconceived notion of the essentially arbitrary detail in military command, was sometimes led to the conclusion that the buck was being passed to him when he received an order to accomplish a certain thing and then was left to his own devices for the ways and means. The wonder is that in the circumstances, no greater confusion or misunderstanding resulted, for the fact has amply been demonstrated that the common ground of action, the mutual viewpoint which will reveal the logical steps to flow from any given premise, cannot be acquired overnight. In the recent war, the bulwark of our allies shielded us in many ways, not the least of which was in minimizing the ill effects of a lack of homogeneous professional attitude among the hastily expanded corps of officers. If we heed the lessons of the war, we will insure the wide dissemination of common bases of professional understanding on the part of all officers, Regular, Reserve, and National Guard.

But, beyond all this, it is essential that from now on the Army frankly discountenance every manifestation of avoidance of responsibility. As was said in a JOURNAL editorial in the September issue—the day of "passing the buck" is past and the "buck passer" must be branded and condemmed. There are all sorts of little ways, as well as big ones, of sidestepping responsibility. A very low-down way is for a superior to throw the blame for the unexpected operation of his orders upon the luckless subordinate who executed the orders, on the ground that the subordinate varied in the execution of the orders from the intent of the superior. A prime essential to loyal support is that a subordinate may *know* that so long as he uses his best energy and judgment in carrying out the orders of his superior, the superior is surely going to back him up to the limit.

Perhaps the meanest trait of all is the spirit which will prompt a leader deliberately to issue an ambiguous order when he himself is in a tight pinch, so that if anything drops, he may shift the responsibility to a subordinate on the ground that the order was misinterpreted and wrongly executed.

These are glaring phases of a spirit which is always contemptible. The Army needs a specific mechanism to recognize and record even picayune manifestations of the unlovely trait of buck-passing, and there should be no quicker route to the back door of elimination than the diagnosis of an incurable case of flinching from responsibility. F.F.C.

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COLONEL PALMER BEFORE THE MILITARY COMMITTEE

Colonel John McA. Palmer, General Staff, appeared before the Senate Committee on Military Affairs on October 9 and 10, having been called to present his views on the subject of reorganization of the army, concerning which the military committees of both the Senate and the House have conducted extensive hearings. The JOURNAL prints herewith nearly all of the report of Colonel Palmer's statement, without other comment than to observe that the editors felt so strongly the importance of Colonel Palmer's expressions on the citizen army, promotion, and the functions of the General Staff, that in order to make room for this report, several other articles have been withdrawn after the copy had gone to the printers, and an extra sixteen-page form has been added to this issue of the JOURNAL.

The CHAIRMAN. Have you any general observations to make about the legislation that is pending before us?

Col. PALMER. I have studied the three principal plans of military policy now before Congress—the one contained in the War Department bill; the one contained, not in a bill but as outlined at the hearing of Gen. O'Ryan; and the one outlined in the Kahn-Chamberlain bill. These all aim at establishing what we have never had before, a military policy of the United States—and before commenting on any one of those three plans, Senator, I would like to mention one or two general considerations which, in my opinion, determine what the strength and form of any military establishment should be.

The CHAIRMAN. Very well.

Col. PALMER. The first question is what is the measure of the war strength. The next question is what should be the size of the peace establishment, and the next is what should be the form of institution in order to have a peace establishment that will develop the necessary war strength. I think this war has demonstrated, that so long as war is a possible contingency, there is no measure of ultimate war strength other than the total man power of a nation; and that the military policy should be so constructed as to develop all or any necessary part of that man power in time to meet any given emergency.

There have been attempts in the past to compute a nation's war establishment from a consideration of other powers that might possibly be enemies; but this is fallacious in principle. The very first requirement of strategy is superior numbers, and the only way to be assured of approaching that as soon as possible is to be prepared to develop the total man power if necessary.

For example, the British worked up a very elaborate plan of placing six divisions on the left flank of the French army in the event of a war with Germany. Of course, it developed immediately after the war began, as Lord Roberts had pointed out, that the only real measure to meet that situation was the total man power of Great Britain. And her ability to carry out the proper measures when she finally saw them was seriously jeopardized by the fact that in sending the six divisions to France she lost a great part of the trained personnel necessary to develop the total man power.

I think that the same principle really develops from the history of all of our great wars. In the Civil War we ultimately had to go to the total man power through the draft. In the War of 1812 the avowed object of the war at that time was to capture Canada. It was a failure. I have no doubt that if the conception of developing the total man power had been appreciated at the time of the Revolution it would have terminated that war very much sooner. Of course, in the recent war we were actually developing our total man power at the time the hostilities ended.

Now, when we come to the measure of peace strength, the time factor comes in. Economy demands the minimum peace establishment through which the war establishment will develop in sufficient time. It depends a good deal upon the frontiers of a country—how close it is to its prospective enemies. Two nations having the same total man power might have very different peace establishments, depending upon the difference in time allowed for deployment in the two cases. I believe that complete preparedness implies capacity to develop all or any necessary part of the man power of the nation in time to meet any given emergency, and that this can be assured only through universal military training.

When we come to the question as to the form of military institutions, I think, sir, that that is very largely a political question and depends upon a consideration of the general system of national institutions, There are two types of armies through which the total man power may be developed. One is the professional or standing-army type. In this the man power is drawn into the army very largely in the lower grades. The function of the citizen is ordinarily to be a private in war. Reserve officers are to be used, but generally in the lower grades and in subordinate capacities. Under this system leadership in war and conduct of preparation in peace are concentrated very largely and necessarily in a professional class.

This is the system of continental Europe, the system that Germany had and Austria had and France to a very large extent. It produces a highly efficient military system, but it is open to certain serious political objections. In such a country intelligent opinion as to military policy is largely concentrated in a professional class. Under such a system the people themselves are competent to exert only a limited intelligent influence on the issues of war and peace. As military leadership and control in war are largely concentrated in the personnel of the professional military establishment, that establishment must be relatively expensive and of relatively large dimensions in time of peace. Under such a system only the brawn of the people is prepared for war, there being no adequate provision for developing the latent military leadership and genius of the people as a whole. The evils under this system may be summarized under the term militarism. For militarism is a characteristic of a particular type of military institution, and is not necessarily inherent in all forms of preparedness.

The second type of a military institution is a citizen army, formed and organized in peace, with full opportunity for competent citizen soldiers to rise by successive steps to any rank for which they can definitely qualify, and with specific facilities for such qualification and advancement as an essential and predominating characteristic of the peace establishment.

An army of this type has, among others, the following advantages:

First. Military leadership is not exclusively concentrated in the professional soldier class. All citizen soldiers after their initial training, are encouraged to develop their capacity for leadership to such an extent as may be consistent with their abilities, their tastes and their civil obligations.

Second. As the war army in this system is identical with the organized citizen army in time of peace, and as the bulk of the officers and noncommissioned officers required for war are assigned in peace to their proper places in the citizen army, the peace establishment of professional personnel is logically reduced to a determinable minimum required by certain specific purposes.

Third. As the bulk of the leaders of the citizen army are included in the civil population as a whole, an intelligent and widespread public opinion is provided as the basis for the determination of all public questions relating to military affairs.

Again, as the war army is identical with the organized citizen army, all plans for national preparedness are simplified into dispositions for the employment of a specific force always organized, always at war strength, and always prepared to function under tested mobilization plans.

Again, as the war army is identical with the organized citizen army, all plans for equipment and armament, all fiscal arrangements, and all plans for the development and control of war industries and the predetermined provision of the necessary personnel therefor, are definitely associated with the obvious requirements of a specific force of definite size and organization.

Again, as with an organized citizen army the minimum number of soldiers is maintained on active service in time of peace, the cost of an effective war establishment under such a system is necessarily reduced to a minimum.

And finally, as all our great wars have been fought in the main by citizen armies, the proposal for an organized citizen army in time of peace is merely a proposal for perfecting a traditional national institution to meet modern requirements which no longer permit extemporization after the outbreak of war.

In studying the three plans of military policy before the committee, I consider that the War Department bill proposes a military institution of the first or standing army type. It relies essentially on a large regular army and proposes universal military training primarily as a means of providing men to fill its lower ranks on the outbreak of war. It does not provide for an organized citizen army and does not provide sufficient training to prepare the young men of the country for membership in such a force, nor does it provide the adequate facilities nor the organization essential to the full development of efficient citizen officers. In my opinion, the War Department bill proposes incomplete preparedness at excessive cost and under forms that are not in harmony with the genius of American institutions.

Senator NEW. May I interrupt you right there?

Col. PALMER. Certainly.

Senator NEW. I wish you would tell us just as briefly as you can something about the War Plans Section of the General Staff, how it is composed.

Col. PALMER. There is a War Plans Division of the General Staff, which includes several branches. One of them is the War Plans Branch which is charged with the preparation of plans for the national defense, with the preparation of coast defense plans, and the plans for the organization of the Army.

Senator NEW. That is it; there is a War Plans Branch that is charged with that particular duty?

Col. PALMER. Yes, sir.

Senator NEW. Did the War Plans Branch of the General Staff prepare the so-called War Department or General Staff bill which this committee has under its consideration?

Col. PALMER. The War Plans Branch was not consulted in regard to the policy underlying that bill. It performed the purely ministerial duty of working out the details of the policy that had been laid down.

Senator NEW. What is the opinion of the War Plans Branch of the General Staff as to the merits of this bill?

Col. PALMER. The War Plans Branch at various times has made recommendations with reference to military policy, and I think I can say that these recommendations invariably embodied these ideas: Universal military training, an organized citizen army, and the minimum regular establishment necessary to carry that policy into effect. These recommendations, in my opinion, are diametrically opposed to the policy outlined in the War Department bill.

Senator NEW. In your opinion as a member of the War Plans Section, how should a plan of national defense be prepared in order to conform to the General Staff act of 1903?

Col. PALMER. The act of 1903 created, in my opinion, Senator, two entirely distinct agencies. One was a General Staff charged with the duty of preparing plans for the national defense and for the mobilization of the land forces of the United States. That was provided in the second section of the act. In the fourth section of the act it created a new supervising agency in the person of the Chief of Staff. In my opinion a plan of military policy is the preliminary plan of national defense, and I believe that the General Staff was the agency created by Congress to prepare such a plan. I do not believe that the Secretary of War or the President or the Congress should necessarily adopt that plan, but as it can be carried into effect only through the action of Congress, it is, in my opinion, the necessary intent of that law that that plan should be submitted to Congress unmodified, but with such concurrence or nonconcurrence and reasons therefor as superior officers might choose to attach to it.

Senator New. Well, was that the procedure in the preparation of the bill under consideration; was that followed at all?

Col. Palmer. No, sir.

Senator New. Tell us what the procedure was, in the preparation of this bill, if you can.

Col. Palmer. I had not returned from Europe when this bill was first prepared; but instructions were issued to the War Plans Division to assume a military policy with a permanent establishment of about 500,000 men, organized into 20 Infantry divisions and 1 Cavalry division, forming 5 army corps of 4 divisions each, and the War Plans Division was instructed to prepare the Tables of Organization and the details of organization under that policy.

Senator New. In other words, the policy was defined and you simply were told to prepare a coat to fit it?

Col. Palmer. To work out the details; yes, sir.

Senator New. Yes; to work out the details. Colonel, I want to ask you another question. During the last session of Congress, probably along in February last, I introduced a bill in the Senate providing for a system of military training. At the time I introduced that bill I said in introducing it that I presented it at that time in order that it might be referred to the General Staff for study and for a report to this committee at the early convenience of the War Plans Branch of the General Staff. Subsequently the bill was referred by this committee to the General Staff. No report has ever been made to the committee so far, but I would like to ask of you if the bill was submitted to the War Plans Branch and if any study was ever made based on it?

Col. Palmer. A letter from the Military Affairs Committee transmitting a copy of the Senate bill known as the New bill—I do not remember the number of the bill——

Senator New. You are referring to the same bill that I am.

Col. Palmer (continuing). Was sent to the Secretary of War, as I remember it, requesting that the General Staff make a report on that bill, and on the subject of universal military training in general. I was a member of the committee to which that letter was referred.

Senator New. Will you please tell us if you can, if it is not inconsistent, who composed that committee?

Col. Palmer. I was the chairman of it. Col. Allen J. Greer of the General Staff was another member, and Col. Tenney Ross of the General Staff was a third member. They are both of them on duty now at the General Staff College.

Senator New. Now you may proceed if you will.

Col. Palmer. This committee realized that the adoption of universal military training would completely modify and determine the character of our military policy, and it prepared a general statement of military policy under the assumption of universal military training and submitted it with the recommendation that it be approved in principle, so that a detailed plan could be worked out. This preliminary paper, outlining the policy as a whole, but not going into minute details of organization, was forwarded by the chief of the War Plans Division.

Senator New. Forwarded to whom?

Col. Palmer. The Chief of Staff. And some time in April the committee was informed that its proposal was disapproved and was instructed to base all plans on the 500,000 Army plan.

Senator New. Could you produce for the committee the recommendations that were made by the war plans section at that time?

Col. Palmer. No, sir; I do not think I could do that.

Senator New. The committee would have to get that from the Chief of Staff if at all?

Col. Palmer. I think so; yes, sir; or the Secretary of War. I do not think I could submit a document of that kind, sir.

Senator New. Well, I presumed not. Mr. Chairman, I would like to suggest that this committee make a request of the Secretary of War that those recommendations be submitted to the committee for our inspection.

The CHAIRMAN. Is there any objection?

Senator FLETCHER. What was the idea of the war plans section of the General Staff, Colonel, with reference to the minimum size of the standing or Regular Army?

Col. PALMER. In that paper, sir?

Senator FLETCHER. No; you spoke about three things you kept in mind.

Col. PALMER. Yes.

Senator FLETCHER. And one of them was the minimum size of the Regular Army. I was curious to know what you had in mind, what number you had in mind.

Col. PALMER. That, Senator, was only indicated approximately, because if this paper had been approved in principle we would have worked it out minutely; but I think that a total of about 280,000 would certainly accomplish all the necessary objects, and that in the actual operation of the system that number might be materially reduced in time.

Senator FLETCHER. That many officers and men?

Col. PALMER. Enlisted strength, sir, about 21,000 officers would be required.

Senator NEW. That would mean, then, approximately 300,000 officers and men?

Col. PALMER. Well, ultimately less than that; but just how much less would depend on quite a number of undetermined conditions.

Senator FLETCHER. The 280,000 included the 21,000 officers?

Col. PALMER. No, sir. It might under the operation of the plan be reduced materially below that, depending very largely on the actual success of the citizen army.

Senator NEW. Just one other question. Have there been any other occasions, and if so how many, when the War Plans Board of the General Staff has made any recommendations relative to a military policy based on universal training?

Col. PALMER. The Chief of Staff, Gen. Scott, recommended a policy of universal military training in the fall of 1916, and it was after that that we made the plan that I have already referred to. That is the prewar plan which was published in the Congressional Record some time in March, 1917. Then, later, the General Staff, at Gen. Pershing's headquarters, without instruction from him, as I understand it, prepared a plan based on the same general idea but calling for a smaller regular personnel than the original plan, and for certain other simplifications due to our increased experience in the war. I saw that plan just before I left France, in December and January. It was prepared, I presume, for the action of Gen. Pershing, but Gen. Pershing did not act on it, I think primarily because he had not been called on for a recommendation of that character, and also because at that time he had not been able to go into it in detail. I do know that it had not been approved by him.

The CHAIRMAN. That was prepared by Gen. Fiske in G-5, was it not?

Col. PALMER. It was originally prepared there, but circulated through the General Staff of the A. E. F. and was not unanimously concurred in; but it was similar in form to the General Staff plan of 1917. Then, again, the basic outline of a plan was drawn when the General Staff considered the New bill.

Senator NEW. No action on any of these recommendations was ever taken?

Col. PALMER. No; none so far as I know.

The CHAIRMAN. You might proceed with your statement. You had covered a discussion of the large standing professional army, and you were about to proceed, I think, to the discussion of the others?

Col. PALMER. Yes, sir.

The other two plans before this committee—that is, the one outlined in Gen. O'Ryan's hearing and the one outlined in the Kahn-Chamberlain bill, both propose a military system of the citizen army type. In my opinion they are both highly constructive propositions and essentially sound. There are certain details, which I believe should be corrected. But there are certain things about this discussion of a citizen army that in my opinion have not come into the hearing at all. That is, just how it should be formed, how it ought to be organized, and what it ought to aim at. Before discussing those plans in detail I would like to present some views on that subject, because I have given a good many years of my life to the study of that question, both on the General Staff and as an individual.

The CHAIRMAN. We would be glad to have you.

Col. PALMER. The main feature of the military establishment of the United States in my opinion should be a trained citizen army organized territorially in divisions, army corps and field armies, in such a manner as to permit immediate mobilization in the event of emergency.

In the initial organization of this force the charter members should be those veterans of the great war who volunteer to enter a unit of the citizen army whose territorial allocation includes their place of residence. This force should be perpetuated by universal military training.

Every young man should undergo military training for not less than six months and after such training he should enter an organization of the citizen army and should be a member thereof for five years, after which he should pass to the unorganized reserve unless after due qualification he elects further service in the citizen army as an officer or noncommissioned officer. The organized citizen army should be mobilized for inspection and team training for a short period of about two weeks each year.

During this mobilization period, maneuvers and terrain exercises should be provided on a sufficient scale to test the effectiveness of mobilization plans and the capacity of commanding officers and staff officers. Battalions and regiments generally, and in populous regions brigades, can be concentrated by marching. Corps and divisional maneuvers should be provided from time to time when appropriations permit the necessary transportation. When and where circumstances do not permit the concentration of large units the capacity of higher commanders and staffs can be effectively tested by appropriate terrain exercises.

All private soldiers who are graduates of the training system should be required to attend at least two annual mobilizations during their period of prescribed membership in the organized citizen army. Officers and noncommissioned officers should be required to attend all such annual mobilizations except when excused by competent military authority. All original vacancies in commissioned and noncommissioned officer grades in the organized citizen army should be filled by the appointment of veterans of the war in civil life and by detail from the Regular Army. In making such initial appointments former veterans of the war, whether in the National Guard, the National Army, or the Reserve Corps, should be eligible to appointment in any grade not above the highest grade held by them with credit during the war and in a unit of their proper arm of the service whose territorial allocation includes their place of residence. Their subsequent promotion should be after such examination, including practical tests at the annual maneuvers or elsewhere, as may be prescribed by the President.

The annual six months' training course should be conduced by a thoroughly trained corps of officers and noncommissioned officers detailed or selected from the Regular Army and supplemented to such extent as may be practicable from citizen officers and noncommissioned officers who voluntarily accept service for such temporary but sufficient periods as may be necessary.

In order to provide for the necessary continuous administration of the organized citizen army in the intervals between annual mobilizations, each unit of the organized citizen army should be provided with a small skeleton staff of officers and enlisted men detailed from the Regular Army.

Officers and noncommissioned officers of the citizen army should be eligible for promotion to any grade for which they are able to qualify under regulations to be prescribed by the President and for assignment to any duty in the Military Establishment appropriate to their rank except such duties in time of peace as obviously can not be performed by persons not continuously on active service. All offices in the Military Establishment requiring the services of persons continuously on active duty should be filled by detail from the Regular Army or from qualified citizen officers and men who voluntarily accept active service for such sufficient continuous periods as may be prescribed by regulations. Officers and men of the citizen army while on active duty should receive the pay and allowances of their proper grades in the Regular Army.

No regular or citizen officer should be assigned to the command of any tactical unit until he has affirmatively demonstrated his capacity to maneuver, command and administer such unit under such practical test as may be prescribed by the President.

Regular officers assigned to duty in the citizen army should be assigned in their actual grades or in temporary advanced grades appropriate to and during the continuance of such assignment.

In time of war all officers of the military establishment should be pooled and assigned either in command of troops or on staff duty according to their tested qualifications and in grades for which they have been or may be tested under regulations to be prescribed by the President.

The organized citizen army should include an organized harbor defense corps at full war strength, with ample replacements as well as a territorial field army organized in divisions, corps and field armies. With 16 training centers located with proper reference to the distribution of military population, each such training center should generate and maintain the personnel for an army corps of two or three divisions. The commander of this army corps provided with a proper staff, should command the army corps and should be responsible for all military activities within his corps area. In the initial organization of each army corps its component units should be given the designation of previously existing local military units, having historic records in former wars, in so far as this can be done without defeating the primary objects of correct military organization and the localization of homogeneous tactical units.

Upon mobilization of the army corps in war the corps training center will continue its training function with the view of maintaining the supply of trained replacement. If the period of membership in the organized citizen army be fixed at five years, each corps area will be able immediately to mobilize a complete army corps at full strength and to fill its replacement depots with trained replacement and will have sufficient surplus strength in trained officers and men to form such new and unforeseen organizations as any particular military situation may require even after necessary exemptions for war industries have been determined. The corps area with its territorial units and its training center thus becomes a continuously functioning machine through which, if necessary, the entire man power of the nation can be mobilized promptly, effectively and economically.

Now, whether such a force as that is practicable depends on whether citizen soldiers can be trained to perform the functions demanded of them under that system. I do not think there is any question about the feasibility of doing that if the citizen army is actually organized. If it is not, of course, there will be no effective machinery for making the necessary tests.

Senator FLETCHER. That plan means not only universal training but universal compulsory service?

Col. PALMER. No, sir, it is a universal obligation to serve in the event of war, but no service except for training purposes in time of peace, no attendance except for training purposes.

Senator FLETCHER. You oblige them to remain in the service four or five years, subject to assembling each year so many weeks?

Col. PALMER. Well, it would not be necessary for any of them to attend more than twice. The unit a man belongs to would assemble annually but the individual private soldier would only have to attend twice. Of course the men who voluntarily accept the opportunity to be officers would voluntarily attend in order to qualify themselves for promotion.

Senator FLETCHER. That is not compulsory?

Col. PALMER. No, sir, that would not be compulsory.

The CHAIRMAN. And you would make the maneuvers that are held during the four or five years of their training a continuation of their training?

Col. PALMER. Absolutely. There would be no service for them.

The CHAIRMAN. You would not have those reserve units subject to call for any military purpose?

Col. PALMER. Except when a sufficient emergency is designated by Congress.

The CHAIRMAN. How about riot duty?

Col. PALMER. I should think, sir, that it would be very much better to have a separate force for that purpose.

The CHAIRMAN. Of course that would not be for training purposes, that would be a military purpose?

Col. PALMER. Yes.

The CHAIRMAN. And would involve the element of compulsory military service?

Col. PALMER. That would be a question, it seems to me, for each State to determine for itself, that is, what particular forces it required——

The CHAIRMAN. Do you remember Gen. O'Ryan's suggestion on that?

Col. PALMER. Yes, sir.

The CHAIRMAN. Of course his suggestion involves the use of this trained citizen army for military purposes in time of peace, by compulsion?

Col. PALMER. Yes. I would be glad to go into that now, but I intended to go into it later.

The CHAIRMAN. You may go on in your own way.

Col. PALMER. But I think this particular point about the qualification of citizen officers is really the crux of this whole question. It all depends on that. The primary thing is that they must be efficient, and I believe that the determination of efficiency is purely a question of fact. If a man alleges he is a major of infantry you can determine it in precisely the same way that you can determine whether an alleged chauffeur is really a chauffeur. Let him try it in the presence of competent judges. That has been the practice abroad, and it is thoroughly feasible. And the same test ought to be applied to regular officers and citizen officers. If a man is a candidate to command a battalion of infantry, say, if you take him with the battalion of infantry under a competent umpire, and give that umpire control for five or six days, with the necessary complete transportation——

Senator SUTHERLAND. Do you mean the umpire or the candidate?

Col. PALMER. The umpire. And then let the umpire give that man a continuing situation for six days, simulating war conditions, requiring him actually to administer, maneuver and march that battalion, you will have a test that will determine that question of fact as closely as it ever can be determined in time of peace.

Whether a man is a regular officer or a citizen officer he should not be assigned to command any unit until his capacity to command it has been demonstrated, and if his capacity to command it has been demonstrated then he should not be arbitrarily restricted to any particular rank merely because he is a reserve officer or a citizen officer. There has been a great deal of nonsense and interested camouflage on that subject. It is purely a question of fact. There is nothing in our history that justifies the presumption that all regular officers are competent to command, and there is nothing in our history that justifies the presumption that no citizen officers are capable of rising to high command. There have been many men with natural military leadership—Cromwell, Forrest, Logan, and many other instances I might mention. With the organized citizen army you would discover such men in time of peace, and put them in their proper places, and multiply their number as much as you can.

So it seems to me, in a complete scheme of National preparedness, that feature, above all others, should be developed. We should develop the natural leaders in the citizen soldiery. We would find a great many of them among the millions that would pass through that system in the course of time if we have universal training, and I do not think there is any question about the practicability of it.

Senator FLETCHER. Where is the place for your National Guard there?

Col. PALMER. In my opinion, sir, the National Guard should go into that organized citizen army. I commanded a National Guard brigade in the fighting north of Verdun, and it had severe fighting. I talked to a great many of my officers on this question, and that was the opinion of most of them I talked to. If we had an organized citizen army under Federal control, that is what they would want to enter. I think the main concern with them would be whether they are to have a square deal in entering it. I think that is the general sentiment of most of them. I have talked to some of them since they came back, and I have heard a number of them say that if there is to be an organized citizen army they want to go in it. They say "If we are to go back to a vague reserve status like our present reserve corps or to National Guard duty, we are through." A number of them have said that to me. I think the point is just this, Senator. We want a citizen army. Those gentlemen of the National Guard, in my opinion, have done an immense public service in this country by keeping alive the tradition of the citizen army, but they have done it under an immense handicap. You can not organize an efficient army—it is impossible to organize an efficient army—for war purposes under the militia clauses of our Constitution. If you should speak to Marshal Joffre or to Marshal Foch or to any great military expert, and say "I will allow you to organize an army. You can do whatever you please with it except you can not train it, you can not discipline it, and you can have no voice in the training of its officers, the selection of its officers," and he would say to you, "But those very things you except and exempt are the absolutely essential things in providing an efficient military force."

I believe that the solution is to form a citizen army under the constitutional clause that authorizes Congress to create and support armies. The service in many respects would be like your National Guard service. The present National Guard personnel should be received into the new force and should be an important element in starting it. They should have the fairest chance. In my brigade there were two regiments. In one of them, a regiment that came from Maryland, the colonel was a National Guard officer, and he was one of the finest colonels I have ever seen. I did not have the opportunity to serve with that division during the period of organization, but its division commander, Gen. Morton, regarded this colonel as one of the best colonels, one of the best administrative colonels, he had ever seen in his long experience in the Army. When I joined the brigade it was in action, it had been checked the day before I joined, and two or three days later we carried a position with heavy loss, and I observed that colonel particularly, and I know from my observation that he is a splendid colonel.

I believe if an organized citizen army should be formed, that colonel and most of his men would want to enter that force, and that they would prefer that to any other status for them. I believe firmly that that is what they wanted the National Guard service for. There has been a great conflict of opinion; but those men entered the National Guard because they wanted to be citizen soldiers, and I believe they would welcome that status, at least all I have talked to—and I have talked to a great many, Senator Wadsworth, who have told me that they specifically objected to that phase of Gen. O'Ryan's plan which would leave them the double function——

The CHAIRMAN. That suggestion of his, that that Federal citizen army should, within the boundaries of the several States and with the permission of the President, be subject to the call of the governors to suppress disorders?

Col. PALMER. Yes.

The CHAIRMAN. Of course his idea there was to substitute some force inside the State boundaries which could be used in place of the militia for the maintenance of order in case of disturbance.

Col. PALMER. It would be feasible from the organization standpoint, there is no question about that.

The CHAIRMAN. But it does bring in entirely new elements.

Col. PALMER. Yes, sir.

The CHAIRMAN. In the first place, it brings compulsory service.

Col. PALMER. Yes, sir.

The CHAIRMAN. And it probably clashes with the Constitution.

Col. PALMER. And, Senator, there is a principle of very general application in military affairs, and that is that as a rule an organization that is designed to perform a double function does not perform either one of them very well.

The **Chairman**. I know myself that the guard has always detested riot duty. They say it is a policeman's duty and not a soldier's duty. Soldiers are the most expensive and most inefficient policemen. That is one reason why New York has established a State constabulary, and Pennsylvania has done the same thing. They can do with a thousand men what it took ten thousand men of the National Guard to do.

Col. **Palmer**. There is another thing about a citizen army that I think has an immensely important bearing on preparedness. If we had a force of that kind and if that was our main dependence in time of war, I think there could not be devised a force that would be less provocative of war, and on the other hand there could not be devised a force that would be more powerful in war, because if that system were in operation for, we will say 25 years, every member of Congress and probably the Secretary of War and the President and all people who influence public opinion throughout the country would have been members of that force. A considerable number of them would probably have had sufficient interest in it to have served for some time as officers. The result would be then that instead of military problems being very largely a matter of mystery and camouflage, the people concerned would understand them just as they do any other public question, and I think that would have an enormous effect not only in avoiding unnecessary wars but in assuring the highest efficiency if war did come.

Senator **Fletcher**. Have you figured out the expense of that plan.

Col. **Palmer**. I should say, assuming that the National Guard is absorbed in it, that it would probably not cost much more than half of the cost of the War Department plan. It would probably provide twice as many men on the outbreak of war as the War Department plan, and its subsequent expansion would be at a very much higher rate than would be practicable in the plan proposed in the War Department bill.

Now, there is one question about these fundamentals of military organization—that is, relation between military systems and international peace arrangements. I do not think they change the essential character of a nation's military institutions. Take France, for example, and with the situation of course in France entirely changed, in that Germany is prostrate, there may also be an international arrangement through which the menace will be very much further reduced. But that is not changing her military institutions. She is simply changing the size and characteristics of her peace establishment. The national policy is still there. The chance of war is more remote, that is all. Her policy is still to develop her total man power if the emergency comes, but under the new situation, instead of strategical deployment being a matter of two or three days, it will be a matter of considerable time. Therefore she is able to reduce the period of training required, she is able to reduce the numbers under arms in time of peace, and she is also able to reduce the elaborateness of her armament program. That is, the essential organization of the machine remains the same, but now that it does not have to function so fast they do not have to elaborate so much of it in time of peace. When we come to a time when there can be no war at all, then necessarily there will be no military establishment at all. But so long as war is possible the only answer to the preparedness problem is capacity to develop all or any necessary part of the total man power in time.

If the plan of an organized citizen army is accepted, the regular personnel should be limited to the minimum number of officers and enlisted men required to perform such continuous functions as obviously can not be performed by citizen soldiers. We will require regular personnel for foreign garrisons. We have certain garrisons we have to maintain because they act as naval bases, or for other reasons. We can not send citizen soldiers to such places. We will have to have a small mobile force for minor emergencies not justifying the mobilization of the citizen army. We will have to keep up the peace establishment of harbor defense artillery.

Then, of course, will come the professional component of the training establishment required for universal military training. For instance, if a regiment should be formed in Maryland and this colonel that I spoke of should be the colonel of the regiment, as he ought to be, it would still be a desirable thing, if that regiment is to mobilize promptly for the annual maneuvers or for war, to provide him with perhaps a regimental adjutant and a sergeant major and a supply sergeant, and perhaps a couple of clerks, so that the necessary continuous administration would be provided. But when you consider that that is a unit of something like 3700 men, of course, that cadre is a very small charge in the way of overhead to keep it going.

The CHAIRMAN. Three or four professionals on duty at headquarters all the time?

Col. PALMER. Yes, that is for purely administrative purposes.

Senator FLETCHER. As I remember what we have heard officers say during these hearings, the large demand will be in the number of men required for training, conducting these training camps. Some have estimated one man to every six. That in itself would call for a tremendous force.

Col. PALMER. When you consider the requirement of getting very efficient training in the time allowed, and when you consider the personnel that you have to have for administration duties, I do not think that would be excessive. You could make the allotment you have mentioned and still come within the total of 280,000. Then, of course, the other elements of the regular peace establishment would be the peace establishment of the War Department and the several staff corps and services. But that would be very much reduced and would be continually further reduced as time goes on. In the recent war we took a great many civilians in to expand these services. Under the citizen army plan they would be in all the time, and the only difference would be they would know their places and what they were going to do, so that the overhead would be very greatly reduced.

The establishment of such a system now of course would be simple. Five or six years from now it would not be so easy, because the trained people to start it would then be too long back in civil life. If it is started now, what it would amount to, in my opinion, would be—it would be perpetuating the Army we have created in this war. It would be converting an immense unproductive outlay into a permanent investment, so that the outlay for this war to a very large extent would be available for a war a hundred years from now. For example, if at the end of the Civil War—we then had a trained citizen army on both sides—and it was largely a citizen army—if that army at the close of the Civil War, when they went back into civil life, instead of being disbanded, had assumed a reserve obligation for two or three years and then had gradually been replaced by each year's crop of young men, we would have had a very economical miltary system, and we would have had a military system that would have found us prepared for the last war. We would have had a functioning machine through which we could actually have developed our man power.

Senator, you were speaking about the total numbers required, and I told you that I could tell you what would probably be the maximum allowance, but there would be a great many factors to be considered in determining the minimum. I would like to give a little more detail on that point, because it is interesting. Of course the conception is—and I believe it is a sound conception—that the number of professional soldiers in a country like ours ought to be reduced to a minimum, to the lowest minimum consistent with war preparedness.

The total number of trained officers and men required for the purposes that I have indicated will be approximately 21,000 officers and 280,000 enlisted men. All of these need not be regulars, because a considerable number of citizen officers and noncommissioned officers may be effectively employed for relatively short periods in the training service. This should be encouraged, as such service by citizen soldiers will tend to increase their qualification for promotion in the citizen army and will greatly increase the efficiency of that force. But while the numbers of citizen soldiers so employed will tend to reduce the number of professional soldiers required, the actual number can not be predicted in advance and can only be determined by experience. It may be said, however, that the enlisted strength of the Regular Army, after the citizen army is fully organized, will not be greater than 280,000, and will probably prove to be considerably less.

The total number of officers provided by the national defense act will be insufficient, as between 9000 and 10,000 more trained officers will be required, but the proportion of these that must be regular officers can not be definitely determined until experience shows the number of capable citizen officers that can be expected to serve for sufficient temporary periods in the training service.

But while the total required strength of the regular establishment is uncertain the personnel required for the several branches of the service is even more uncertain. There will be some branches of the new army that are not recognized in the national defense act at all, and, on the other hand, certain branches of the service, such as the Cavalry and Coast Artillery, are provided in the national defense act in greater numbers than will be required in a regular military establishment based on providing a regular nucleus for an organized citizen army.

Again, the ratios of strength between a given arm in the citizen army and the corresponding nucleus in the Regular Establishment will be different for different arms of the service. For example, as mechanical transport is highly developed in civil life, the mechanical transport of the citizen army will require a relatively small overhead in the Regular Establishment, while others, like the Air Service, will probably require a higher percentage of regular personnel.

It is obvious, then, that there must be a readjustment of the allotment of personnel to the different branches and that the ultimate percentages in the several branches, as well as the ultimate totals of the Regular Establishment as a whole, can be precisely determined only by experience.

The solution of this problem contains enough inherent difficulties, even if the army could be trusted to work it out in a strictly scientific manner. But this is out of the question on account of the irrational legal organization of the commissioned personnel of the Regular Army. The problem is to provide a minimum personnel sufficient to perform the functions of the Regular Army. It will result, if it is done honestly and scientifically, in reducing the number of regular officers in some branches of the service; it will involve increasing some branches a little, some of the branches a great deal, and it will involve forming some entirely new branches of the service.

If this situation should arise in the Navy, it would be met as a simple administrative problem. If the development of battle cruisers should reduce the requirement for some other type, there would be simply an increase in the roster for one and a decrease in the roster for the other. If the development of aircraft and submarines should be increased at the expense of the dreadnaught, the number of officers serving on the ascendant types would be increased and the number serving on the declining type would be reduced. This would be possible because Congress provides a total strength in the several grades of the Navy and does not prescribe a definite number of officers and a separate line of promotion for each separate naval function. Nor does it prescribe the total numbers, nor much less the numbers of the several grades that must rigidly and definitely constitute the crews of the different types of war vessels. If Congress should provide a separate, rigid allotment of personnel and a separate line of promotion for every naval function, it would be impossible to solve the problem of proper equilibrium for the service as a whole, as the personnel pertaining to each function would then find a natural human interest in magnifying the relative importance of that function. The relative importance of various naval types would be determined not by proper tactical and strategic requirements, but by an unscientific compromise of conflicting partisan views. And yet that is precisely the condition with reference to organization in the Army. Congress fixes the total strength and detailed organization of the personnel assigned to each major military function and provides a separate line of promotion for each. So long as this system prevails it will be impossible to provide a flexible and economical military organization properly adjustable to changes in the military art. Under this system each branch of the service is and always will be tempted to overstate its proper personnel requirements. Under this system it is impossible to make a scientific readjustment of the authorized commissioned personnel to meet the requirements of a new policy in which the regular personnel is to be adapted to its proper function of providing the necessary minimum professional cadre for a great citizen army.

I have frequently heard members of Congress say that it is impossible to find any unanimity among Army officers as to the needs of the military establishment. This is undoubtedly true, and I have stated the reason. When promotion is uniform throughout the service, as in the Navy, and not dependent upon changes of tactical organization, the personnel is content to leave questions of policy to the limited number of officers trained to make a proper scientific determination. In the Army every second lieutenant is forced to form his views as to what the organization of the Army should be long before he knows that there is such a thing as a science of military organization.

Senator CHAMBERLAIN. Do you think that system would be possbile to be transferred to the Army and Navy?

Col. PALMER. Yes; I do. I do not think there is any question about it.

The CHAIRMAN. This War Department bill takes quite a long step in that direction, although it does not go as far as establishing a single list. As you undoubtedly remember, on page 3, line 7, you will find that language which would authorize the recommissioning of all officers of the line, all general officers of the line.

Col. PALMER. Yes, sir.

The CHAIRMAN. And from that point on they are to be detailed to the different branches, staff corps, and even to the technical services.

Col. PALMER. Yes, sir. I think that principle of flexibility ought to be carried just as far as it can be carried.

The CHAIRMAN. There is no doubt about the correctness of that theory, in my judgement; but I wonder whether it is wise to permit the indiscriminate detail of officers in that way, in view of the very intricate and scientific specialties that have grown up in the waging of war.

Col. PALMER. Well sir, under that system you could make exceptions of any service you cared to; for instance, you might apply the single list to the combatant arms. Take an instance like the Medical Corps——

The CHAIRMAN. They are the exception here.

Col. PALMER. They would be carried along, as I understand they are in the Navy, by having running mates in the line of the same length of service, and they would be promoted in accordance with the promotion of their running mates. You could extend that to any service you pleased. There was a strong argument, presented by Gen. Squier yesterday. But if you do not limit it at all and do as they do it in the Navy, where you assign men to proper special functions and are not restricted as to how you do it, it seems to me you meet all the requirements of specialization and the very important requirement of readjustment. That is where we are tied up in the Army.

The CHAIRMAN. Everything around you is in a state of flux and you can not move. You may proceed, Colonel, in your own way.

Col. PALMER. In order to correct the conditions I have just described, and in order to make it possible to compute the minimum requirements of the Regular Army scientifically, I believe that the following principles should be embodied in legislation:

(*a*) The aggregate commissioned and enlisted strength of the Regular Establishment and the total number of officers and enlisted men in each of the several grades of the military establishment as a whole should be fixed by the Congress. The number of officers and enlisted men assigned to the several branches of the service and the detailed organization of each of such branches and services should be fixed by regulation.

(*b*) Whenever a vacancy occurs in any grade below that of brigadier general, the officer in the next lower grade having the longest commissioned service, if duly qualified for promotion, should be promoted.

The CHAIRMAN. You do not believe in promotion by selection then?

Col. PALMER. Yes, but I do not believe in the form of selection that is in the War Department bill. The form of selection that I believe in would be provided in the citizen army, that is, you would actually try out these men in time of peace; you would actually fit the round peg into the round hole in time of peace; you would have the data for selection. I believe I have a statement here of a solution of the promotion question.

The Chairman. We do not want to interrupt you if you had not finished the line you were on.

Col. Palmer. I will come to that a little later, then. I have already indicated the total regular enlisted personnel ultimately required under a citizen army policy will not differ greatly from the total personnel authorized under the national defense act. But if the citizen army policy should be authorized today, it is obvious that for a considerable time there will be additional requirements. Until the process of demobilization is complete and during the transition to the permanent organization, each of the supply and procuring departments will require a greater personnel than will be necessary after the transition is complete. We still have considerable numbers of troops in Europe and Siberia, and the exact time of their return and demobilization cannot be predicted.

Under the citizen army plan it is contemplated that a small regular mobile force should be provided for duty as border patrol and minor emergencies. Until the citizen army is actually organized, the troops required for these purposes should be provided on a more liberal basis. In my opinion, if Congress should authorize the President to maintain not to exceed 380,000 enlisted men for two years and to retain not to exceed 16,000 temporary or reserve officers for the same period, there would be ample personnel to meet all temporary requirements, to establish the foreign garrisons, to maintain a reasonable emergency force, to organize a citizen army and to inaugurate universal military training. Before the end of that time the extra personnel employed in demobilization would complete their work and be discharged, definite experience would be obtained as to the number of citizen officers and men available for duty in the training service, and the precise determination could be made as to the proper personnel of the regular establishment.

I think I can illustrate this whole conception by a rough diagram I have here. Our conception has always been that in time of war we are going to fight with a citizen army and that we are maintaining the regular peace establishment in some undefined way as the nucleus of the larger war force.

In this diagram the small rectangular area on the left represents the permanent establishment; the large, vague, uncertain figure "B" on the right, represents the citizen war army, absolutely indefinite, no determination as to how it is to be organized, or anything about it. That is the way it has been in the past, and for that reason our war plans have been more or less mere ropes of sand, because we did not know what we were going to have to carry them out with.

Now in that uncertain war army, we will say, is to be an engineer contingent, which I have represented by the vague segment marked E'. We do not know anything about that either. We do not know what the total is going to be, and therefore we do not know what this engineer component is going to be. Down here in the regular rectangle we have the smaller rectangle E, which represents the necessary peace-time component to develop E'. But the Chief of Engineers does not know anything about it. All he can do is to estimate as high as possible, and as all Engineer officers have a separate line of promotion based on getting as much as you will give them, there is every incentive to make that and every other component just as big as possible.

(The diagram referred to was passed around and examined by the members of the committee.)

Now, if you replace that vague, formless conception by an organized citizen army, then the size of that force becomes absolutely precise. Instead of measuring from the regular establishment to the citizen army, it ought to be figured back the other way. Determine what the citizen army is going to be and then figure back to the necessary regular component to generate it.

For instance, you have then a certain definite percentage of this total force that are going to be engineers. The proper engineer contingent then in the Regular Army is the minimum number of officers and men required to generate that. Thus, under the old system you can not compute what the size of the Regular Army should be in time of peace—there is no basis for such computation. But assume the organized citizen army and you can compute it as precisely as you can compute the members of a bridge or any other structure that really exists, you can figure out just what it ought to be in whole and in part.

The CHAIRMAN. That is a very apt illustration.

Col. PALMER. I would like to make one or two references now to Gen O'Ryan's plan. In the main it is constructive and sound. It provides for an annual training under a trained cadre. It proposes an organized citizen army raised under the constitutional power to support armies and not under the militia clauses of the Constitution. It proposes a territorial organization, a system of annual maneuvers and full Federal control, and those are the essential features, in my opinion, of a correct and economic military policy.

There are certain statements in Gen. O'Ryan's hearing before the committee, however, which I believe are erroneous, and I am very much inclined to believe that if Gen. O'Ryan had access to some of the information I have he might agree with me.

In the first place, in his computation, as to the size of the Regular Army required, he says that we practically do not need any troops for the foreign garrison because their tenure depends upon the Navy, and if the Navy keeps the sea that will determine the whole thing. Well, now, as a matter of fact, there is nothing that is more essential to the Navy in its plan to keep the sea than to have certain secure bases to fall back on, and of course that would imply sufficient garrisons for Oahu and Panama and possibly some other places. It is quite obvious that the duty of garrisoning those places must be performed by soldiers and that it can not be performed by citizen soldiers.

Gen O'Ryan, instead of proposing six months' training, proposes three months' training, followed by armory training, eighty hours per year for two years and nime months. I believe that six months would be better for the individual recruit, so that he can take it and get through with it. The night work is all right throughout the year, but in my opinion it is better to get through with the close order work for the recruit and devote the night work to the further training of the officers and noncommissioned officers of the citizen reserve army. His three months' training, in my opinion, is too short to secure the educational and vocational advantages of universal training. It takes more time than that to correct certain bad mental and physical habits that can and ought to be corrected by universal training, and it takes more time than that to develop certain good habits that ought to be developed. I think his plan would be measurably practicable in cities and in thickly settled parts of the country, where in the past the Natiohal Guard has been developed to the best advantage. I think it would be absolutely impracticable if it becomes universal and you try to extend it throughout the country.

I think the plan would also be more onerous for the individual man and that it would be a greater drain on business and that it would be better for the average soldier to take his individual training once for all. Then you say to him, practically, "Now you have had your six months' training; you go back into your home infantry battalion (or whatever his arm is), and you are going to be subject to a war call there, if one comes within the next three or four years. If you are content to go to war as a private, you are through; but if you want to rise, if you have ambition to be a leader, you will have to take such additional time in training as may be necessary to qualify you to go up step by step." If there is six months once for all for the private, then all of the time devoted to training during the year can be devoted to the more important object of developing officers and noncommissioned officers.

I think that the economies proposed in Gen. O'Ryan's plan,—that is, his idea of having two or three crops of three months each through each year—would not work out very well. There would be certain classes in mid-winter, for instance, that would not get very much out of it, that would not have the proper training.

The CHAIRMAN. I think he had in view differences in climate geographically in the United States in that suggestion.

Col. PALMER. Well, it might be you would have to shift your training cadre.

Senator NEW. Yes, I am sure he had that in mind.

The CHAIRMAN. You could save in the personnel on the training cadre by having them work in the summer and work in the south in the winter.

Senator NEW. Is it essential that the four months period should be at any particular time of the year? Is it not possible to arrange that on the zone theory, so, for instance, that a farmer's boy in Indiana or Illinois,'our section of the country, need not have to go to the camp during the harvest season, but could go at a time of the year when he could be best spared from the farm?

Col. PALMER. Well, sir, I have been thinking, of course, about a minimum period of six months. Now if we have one training period of six months, the training cadre will really be occupied throughout the year. For six months it will be busy training recruits. For at least another month it will be engaged in work connected with the annual maneuvers. That will leave five months. From this must be deducted some time for leaves and furloughs and necessary rest. The remaining three or four months it will be busily engaged in conducting schools for the officers and noncommissioned officers of the citizen army, and in reorganizing the training service for the next year's class under universal training. The season should culminate in the annual maneuvers. These would be, say, in October. That would fix the end of the six months' training season about the end of September, and would carry you back until about the 1st of April for the beginning of the six months training.

If you tried to bring in the six months of winter, too, you would break down your training cadre and the men who got the training then would not be so well qualified to enter the citizen army.

Senator NEW. I agree with you as to what would be ideal entirely but it occurred to me that that season would interfere more seriously with the farmers in the country from which you and I come, than to take them during the winter months, say, and train them, for instance, in the South. I am just considering some of the very vigorous objections that are going to be interposed on the part of the people to any plan for universal military training that may be suggested, and considering what we may have to accept in lieu of what we might regard as ideal.

Col. PALMER. Well, sir, those of course may be necessary compromises and you would have to be the judge of the relative values. There is no question about that.

Senator NEW. But I wanted to get your views on it.

Col. PALMER. In my opinion you would sacrifice a great many advantages that the people themselves would recognize if they understood them. Now, for example, if you reduce the period of training, we will say, you will also reduce the amount of training received by those classes that take it at an unseasonable time of the year. You save a certain amount of money on that in the cost of training. But you will sacrifice a corresponding degree of efficiency in the organized citizen army. Now, as to your regular establishment, which is the most expensive element of the system—to reduce its cost to a minimum you have to have a citizen army that will mobilize very promptly, but if you reduce the time for that, assuming that you retain the same amount of security, you have to increase the regular establishment accordingly. And I believe—I don't know of course how people would feel about it—but I believe if I had a son, the thing that you would have to convince me of would be that he needed training and that the country was entitled to it, and if I was convinced of that, then I believe I would want him to get it so it would be effective. I believe ultimately our people are senible enough to look at it that way, sir. But there would be a material loss, in my opinion, to the individual in reducing the period below six months—there would be a very great loss—there is an economic by-product from universal training, and you would reduce that materially.

General O'Ryan also proposed, for a force of a million and a half men, two years and nine months service or membership in the organized reserve. In order to do that, he ignores replacements and the possibility of forming new units, and the uncertain requirements of war industries when war comes. The result is that when he deploys that force it may be theoretically at the strength of a million and a half, but he will have to go into the unorganized reserve and take men who have passed out and bring them back into the service in order to raise his war establishment to full strength.

Now, in my opinion, it would be better to keep the men a couple of years longer and carry then frankly as over-strength in their units. You could still have it that each private would attend only two annual maneuvers, just the same, but the advantage would be that a regiment of infantry in the organized citizen army, which is mobilized say at the strength of 3700, would actually carry on its rolls a thousand or perhaps fifteen hundred more. Then when it mobilized you would know that it would mobilize at war strength and that the over-strength would go into the depots and replacement depots. It may happen that in a particular locality there will be a big drain for certain war industries, and those men would have to be dropped. One of the advantages of the organized citizen army is that all those requirements can and should be anticipated. It would not increase the burden of the individual in the slighest. If you figure that three years is the theoretical time required to make your organized reserve contain enough men to mobilize at the strength you propose, it would be better to keep them in it—just keep them on the rolls— a year or two longer in order to provide for replacements and other contingencies.

The Chairman has already referred to the point in Gen. O'Ryan's plan about "duties similar to those required of the National Guard," as Gen. O'Ryan stated it. That is, that these citizen army units in each state would be at the disposal of the governor for State purposes. I think it is always a good principle that there ought to be different organizations to perform different functions. There would be some upsetting of mobilization plans, which, however, could be met by proper arrangements. That is, we would suppose you had a division in Nebraska and on the eve of war a regiment or two were being employed by the governor for State purposes. Your mobilization would be thrown out. That can be met by organizing surplus units. But suppose you have a division assigned to Nebraska and you mobilize it and send it out and then some State emergency occurs and there are no State troops there at all. I believe it would be better to have separate forces for the two separate functions. My strongest reason for believing it is objectionable is that that is objectionable to National Guard men themselves, in so far as I have talked to them.

Gen. O'Ryan also refers to the preservation of names and traditions of old organizations. That is an immensely important thing. I think it is one of the strongest features of the citizen army that it is localized; that so far as practicable, the men from the same community and under their natural local leaders go into war together. I think it is very important for morale and efficiency and economy; but when you come to the initial organization of the force, if that is emphasized too much it may get us into serious difficulties. For example, suppose there is a large city that, before the war, had four National Guard regiments in it, and then during the war those National Guard units were merged into war-organization units and got certain new numbers; then during the war two National Army regiments were also raised in that city. Now, suppose under your quota in organizing the new citizen army your new organization is going to call for four regiments in that city. You are going to have an embarrassing question. It is a local question. It ought to be carried out to meet the views of that city and State. I do not think we could work it out in the War Department without making mistakes on it. Consider a State that would furnish only four regiments to the new citizen army. We ought not to superimpose four regiments one on the other—that is, take them at large all over the State; each regiment ought to be taken from a part of the State containing approximately a fourth of the population of the State. If you do, then you can mobilize it quicker in time of war, and you can perhaps mobilize for your maneuvers by marching and save a great deal of expense, but if the first regiment is drawn from all over the State and the second regiment is drawn from all over the State and the third regiment the same way, then of course no one of them can be concentrated either for war or for maneuvers without the maximum amount of cost. So it seems to me that the primary things are to make a sound territorial organization——

Senator **Thomas**. Would you carry that further by localizing the companies?

Col. **Palmer**. I think it could be carried for the Infantry as far as the battalion. There is a limit beyond which you can not carry it. I think it is a principle we should carry out as far as we can. But I believe if you adopted that principle there would be a delicate, special local problem in almost every State, and it would probably be very desirable in working out the necessary regulations for the War Department to have the advice of National Guard officers and National Army officers on it, because there are a great many difficulties in it and if you commit yourself too far on it it may be embarrassing.

The **Chairman**. Have you finished your discussions of Gen. O'Ryan's suggestions?

Col. **Palmer**. Yes, sir.

The **Chairman**. Did you care to comment on his suggestion that the National Guard or the National Reserve Army, whatever name is given it—he did not seem to care what name was given to it—should have representation upon the General Staff?

Col. **Palmer**. Mr. Chairman, I think that if you pass any law on this subject you will have to leave a great deal to regulation. Now, my branch in the General Staff is the branch that would probably have to prepare a great many of those regulations in so far as they affect organization. It would be of the very greatest advantage to us, to the officers in that branch, to have citizen army officers actually working with them on that question, for two reasons. We have a lot to learn from them in regard to the local difficulties of the problem; and, in the second place, they would come into our branch and see some of the war plans and learn of other difficulties that we have to deal with in connection with this problem. I do not think it would be a good idea to have a separate bureau or agency for that purpose, but for us to work with them on the problem of the citizen army would be the most desirable thing.

The **Chairman**. No; I did not mean to suggest a separate bureau or agency inside the General Staff or attached to it composed solely of citizen officers; but a provision of law making them eligible for membership or detail to the General Staff at the pay and emoluments of their grade for a period of years, say four years or three years, or whatever seems wisest, and the percentage fixed in numbers.

Col. **Palmer**. Oh, if we are going to have that kind of an army we have got to rely on the citizen soldiers to help us work it out properly; there is no question about it.

Senator **Chamberlain**. Do you not find that as a rule the Regular Army officer has not the same civilian touch as the man who is called from a State organization?

Col. **Palmer**. I think that is most undoubtedly true, Senator; it is unfortunate we can not get together better. I have always believed that if I could have a couple of officers like Gen. O'Ryan, and a couple of officers of my own branch, and a couple of National Army officers to work together on the question of the proper military policy for the United States, we would get together within a week and come to a unanimous agreement as to what it ought to be.

Senator **Chamberlain**. I believe so, too.

The **Chairman**. I haven't the slighest doubt about it. The thing that has stood in the way of it is that the citizen officer, whether he was a National Guard or a National Army officer, has had no legal status. He has no privilege of conferring. It takes even a special order, I believe—and it is exceedingly difficult to get it for him—to admit him to Leavenworth or to any of your post-graduate schools. Lots of men have wanted to go there and have found the greastest difficulty in going. I think it is fair to say that there have been a good many Regular Army officers that I do not think wanted them to go there. I remember when the National Defense Act, Senator Chamberlain's bill, passed Congress in 1916, there was a provision in it giving National Guard officers representation in the General Staff, and the Army officers fought it bitterly, and it was knocked out in conference. If they had had one year of contact it would have done both of them a lot of good.

Col. PALMER. I have always thought so. My first tour of duty on the General Staff was in 1911 and 1912, when Secretary Stimson appointed me a member of a committee to make recommendations in regard to military policy, and I specifically recommended at that time that arrangements be made for some National Guard officers to work with us. We could have gone further with our recommendations, I have not the slighest doubt.

The CHAIRMAN. Some of the older officers of the Army would not stand for it if they could help it. I think their attitude has changed in that respect.

Col. PALMER. Oh, yes; it has. I find all along the line that the point of view of Army officers has very much cleared since this war.

The CHAIRMAN. Now you were going to discuss the Kahn-Chamberlain bill.

Col. PALMER.. The Kahn-Chamberlain bill, it seems to me, proposes the same general policy that is embodied in Gen O'Ryan's plan, and I believe that it would tend to avoid the objections that I have mentioned.

I feel quite satisfied that if a citizen army could be formed under the general provisions of the Kahn-Chamberlain bill, with a provision added giving it sufficient regular personnel to tide over the emergency, that we could work out under it a military policy of probably the maximum efficiency and economy.

Senator CHAMBERLAIN. And that leaves a good deal to regulation?

Col. PALMER. Yes; it does.

Senator CHAMBERLAIN. Would you still further modify that?

Col. PALMER. I think you will have to leave it to regulation, Senator, because it is a matter, many features of which ought to be determined experimentally.

Senator CHAMBERLAIN. I did not mean to modify that particular provision, but would you make modifications in the general outline of the bill itself?

Col. PALMER. The Kahn-Chamberlain bill?

Senator CHAMBERLAIN. Yes.

Col. PALMER. I do not think it would be necessary, I think the bill would operate. The question as to the details of the method of inducting into the service I have not given very much study to.

Senator CHAMBERLAIN. And I would like, and I am sure the committee would like, to have you, or some one under your direction, take that bill, which in its general outlines seems to meet your approval, and make such modifications as you might deem advisable and given the committee the benefit of your views.

Col. PALMER. I think that that bill might be amended in the last few sections so as to make a complete solution of the problem.

Senator CHAMBERLAIN. I think the committe would like to have you have those changes in it submitted to them in the form of a letter, or embody it in your testimony if you see fit.

Col. PALMER. All right, sir. I will get at it as soon as I can, sir. I had already made some reference to this question of promotion. I believe that the formation of an organized citizen army in which it would be practicable to try officers out in time of peace would prevent in the future practically all of the difficulties with reference to personnel that have occurred during this war, because every man, every officer, with every unit and every staff would get a trial, and he would be replaced in the event of inefficiency, and in many cases in justice to him he would be assigned to some other function that he could perform well.

I believe that something like the following would make a complete solution of our personnel problem.

1. Promotion up to and including the grade of colonel should be by seniority on a single list based on principle on total commissioned service. A board of general officers should be convened annually and should divide all officers in their several grades into three classes according to their records:

A. Those worthy of immediate promotion;

B. Those who should remain for the present without promotion, and

C. Those who should be eliminated.

The classification by this board should not be subject to revision by any other authority. Promotion during the ensuing year to all grades below that of brigader general should be made by seniority on the single list from among class A officers in the next lower grade. Officers of the Medical Department and chaplains should be extra numbers in all grades and when in class A should be promoted with their running mates on the general list.

The names of all officers in class A should be published to the service annually.

In essentials this is closely allied to the promotion system upon which the efficiency of the German army was based. That is, in any group of officers fit to be promoted the senior should be promoted, but nobody should be promoted by seniority who has not proved his fitness for promotion. If the classification were made annually and a man should be in class B this year, he would have a stimulus, he would have a chance to get into class A next year. It would give all the advantages connected with the other features of the citizen army, all the advantages of selection, and it would give an opportunity to equalize promotion. It seems to me that the curse of our promotion system is this great inequality of promotion. Down there at the General Staff College now there is an officer with 21 years' service, a colonel simply because he happened to be in the Field Artillery, which got a large legislative increase. There is another officer down there of 28 years' service who is a lieutenant colonel because he happened to be in the Infantry; and yet this Infantry officer, a man of much greater experience, was a very brilliant division commander during this war. If you take selection and put it on top of that, the defect of inequality is not corrected by selection at all, it is made worse.

Senator CHAMBERLAIN. You know there has always been a great protest against promotion from a single list. The different branches of the service usually object to that, and that grows out of the reason you now suggest, they each want to have promotions in their own branch of the service.

Col. PALMER. Yes, sir.

Senator CHAMBERLAIN. For instance, a Cavalry officer might be slower of promotion than an Infantry officer, or an Infantry officer might be slower of promotion than a Cavalry officer, with the result that we have unequal promotions in the Army now.

Col. PALMER. Yes, sir; that is true.

Senator CHAMBERLAIN. And yet whenever they have talked about a single list there has always been a kick.

Col. PALMER. I think the idea has grown in popularity to such an extent that a great majority of thoughful officers believe in it.

Senator CHAMBERLAIN. It looks to me as if it were a fair way to do it.

Col. PALMER. It could be put into effect now much better than in the past. This war has demonstrated that a class A officer in any combatant arm, if you give him an opportunity for a little more training, will go ahead of a class B officer in any other arm in a mighty short time. There have been many instances of it. In the National Defense Act there was a provision providing for a great increase of the Field Artillery, and there was a provision for officers from other arms to go into the Field Artillery. I think that those transfers were discouraged as much as possible. I think that Field Artillery officers wanted to get as much of that promotion as they could and the transfers were discouraged as much as possible. They did not want to share it with anybody else. The idea was that an officer could not go into some other arm and learn its mysteries in such a short time, and those who did go in suffered in relative rank. They were placed so they would lose in relative rank by going, although it was the intent of Congress, in my opinion, to take an over-expanded arm and help it out by giving it experienced officers from other arms.

Senator CHAMBERLAIN. That was the purpose.

Col. PALMER. Yes, it was discouraged as much as possible, and yet, so far as I know, the Field Artillery officer, who most conspicuously distinguished himself during the war as a Field Artillery officer, first as a regimental commander and then as a brigade commander, was an officer who was in the Cavalry until after the National Defense Act passed. There is an awful lot of camouflage about it, Senator; it is not so terribly mysterious. I think the mystery is exploited largely, perhaps unconsciously, to preserve the advantages of the promotion.

Senator CHAMBERLAIN. A man who is a successful commander to a large degree is a man who understands human nature and knows how to handle men; is not that true?

Col. PALMER. Yes. When you consider that the general officers are men who are going to command combined arms, that it is a very decided advantage for an able officer to go into another arm. In the Army the differences in functions are no greater than the differences in functions in the Navy, in which there is a constant transfer of personnel. Of course, if it were necessarily followed that the man promoted under the single list should go into the other arm—that particular individual—that would be a bad thing, but that can be avoided. It can be avoided by anticipating requirements and letting the officers who go over be officers who select the new arm and have some additional training before they go over.

The CHAIRMAN. Will you explain again how you would take care of that system of promotion from a single list, with the exception of the Medical Corps and perhaps the Signal Corps and Ordnance Corps?

Col. PALMER. We will say we admit the practicability of this system, so far as the combat arms are concerned.

The CHAIRMAN. Yes.

Col. PALMER. Now, then, I graduate from West Point and go into the Infantry. I will be promoted by a single list. But in the case of some medical officer who goes in at the same time, you do not want to transfer him to the Infantry and Cavalry. You just make me his running mate, and if he is a competent man, he will be promoted when I am promoted. He will be promoted when the line officer who is his running mate is promoted.

The CHAIRMAN. Provided there is a vacancy in the Medical Corps of the next higher grade? You cannot promote him until there is a vacancy?

Col. PALMER. Yes, you can, Senator—in this way. You keep your total of the Medical Corps constant. It would involve some fluctuation in the numbers in particular grades; that is, it might be that it would increase the number of colonels and, correspondingly, the number of liuetenant colonels would be decreased. For an arm like that it would keep their total number constant, but the allotment to the different grades would fluctuate.

The CHAIRMAN. What would be the controlling factor then in that fluctuation? You have a single list, the combatant arm, including Air Service—which I think the committee is disposed to call a combatant arm,

Col. PALMER. It should be; yes.

The CHAIRMAN. You have a single list for all the combatant arms and you promote from that single list. Would that promotion be apt to be faster than it would ordinarily be in the Medical Corps?

Col. PALMER. I think it would be slower than it is now. In any branch of the service where the initial grade is first lieutenant, they ought to be given a constructive increased length of service to start with. As I have stated here—well, I have not come to that point. Shall I go on?

The CHAIRMAN. Yes; go ahead.

Col. PALMER. The names of all officers in class A should be published to the service annually.

2. An officer placed in class C should be examined by a board to determine whether his service has been honest and faithful. If the board finds that it has, he should be placed on the unlimited retired list, with pay at the rate of 2½ per cent for each year of active service, not exceeding 75 per cent, unless his commissioned service is less than 10 years, in which case he should be discharged with one year's pay.

If the board finds that his service has not been honest and faithful he should be discharged without pay.

3. The relative rank of officers in all grades below that of brigadier general should be determined by their relative seniority as fixed by the single list.

The effect of that, in the instance I gave of those two officers in the staff college, would be that this distinguished Infantry officer, when he does come into the grade of colonel, would become the senior, as he should, of the man of seven years' less service, who happened to arrive there a little sooner.

Finally, the original single list should be formed by merging the lineal lists of the several branches into one list arranged so far as practicable in the order of total length of commissioned service. Officers of the Medical Corps and chaplains should be credited with two moreyears than their actual service. After the list is once formed, a newly appointed lieutenant should be placed at the foot of the list and officers of the Medical Corps and chaplains should be placed immediately below officers of two years' service.

Now you could take any other arm you wanted to make strictly a specialized arm and treat it in the same way.

The CHAIRMAN. Your suggestion would destroy the permanent commissioned personnel of the Engineer Corps?

Col. PALMER. Yes, as it stands. But they might be expected also. At first glance, an Engineer officer might think that it would be a disadvatage to him; but I think after more careful reflection he would feel that he would rather in addition to his service in the Engineer Corps be in the line as a whole, so he could have better access to command if he develops in that direction.

Senator CHAMBERLAIN. It would practiclly interfere with all of the permanent corps, would it not?

The CHAIRMAN. There are only two—Medical Corps and Engineers.

Senator CHAMBERLAIN. The others are all detailed except the new men that are left over.

Col. PALMER. There would be some good reasons for placing the Engineers in the same category as the Medical Corps.

The CHAIRMAN. It is a puzzling thing to know what to do with the technical corps.

Col. PALMER. Senator, if that question of equalizing promotion were a mere question of equity, a mere question of individual justice, I would not give it a moment's thought; but the reason in my mind why it is imperative, is that you can not get an honest computation of what the requirements of the Army are until you do it; because there is always an incentive for this line of officers, along this line of promotion on this particular function, to magnify that function as much as they can; they are bound to do it. I can give an instance of it. About 1907 we separated the Coast Artillery and the Field Artillery. In forming the new regimental organization the Artillery Board— I believe there was a board—proposed the four-gun battery as opposed to the six-gun battery, and they urged some very important advantages for it, and those advantages undoubtedly existed. There is a certain technical advantage in reducing the number of guns from six to four. It increased the number of captains by 50 per cent, but there was an advantage in it. They took that from the French, and I have no doubt that was communicated to Congress, but they did not communicate to Congress the fact that the same thing was considered in the German Army and that the Kaiser placed one of the greatest field artillery experts, Gen. Von Rohne, in charge of an investigation, to look into that for the German Army, and that Gen. Von Rohne reported that there were decided technical advantages in the change, but not sufficient to offset the increased cost.

Now, there is no question about it being a somewhat better organization; but our artillery officers went the French one better. They succeeded in adding on to that, a provision under which we have more brigadier generals, colonels, and lieutenant colonels to a given number of guns than any other army in the world. For example, under our organization, the divisional artillery must have a brigadier general, three colonels, and three lieutenant colonels. That is, each two groups of three batteries form a regiment. But during this war the divisional artillery of many French divisions was commanded by lieutenant colonels, or colonels. I remember one particularly, a lieutenant colonel, who was commanding a divisional artillery, and I asked him why he was not promoted, and he said, "Well, I am too young." He said, "I can not be promoted until I have served a little longer as lieutenant colonel." He said, "The effect would be, that it would be promoting me too much ahead of senior officers of other arms." In other words, they wanted specifically to avoid that.

Now, there is no question about the merits of the four-gun battery; there is no question about it, even though secured at increased cost. But all that overhead was not necessary; and, so far as the inefficiency of the six-gun battery was concerned, I do not think that any of us who ever happened to be in a Boche barrage, felt that the German artillery was hopelessly inefficient on account of having six guns to the battery.

That is an example of the effect of a separate promotion list, and it could be carried further, too—the effect of a promotion list where the promotion is along the line of one particular function. The more technical that function is the more easy it is to impress members of Congress as to its importance.

The Chairman. Now, to speak frankly, let me give another illustration, not of what has occurred in the past, but what may occur in the future. You have fixed an Infantry regiment at 3700 men. The experience of a few years may persuade some portion of the Army that happens to be in control that 3700 is too big for an Infantry regiment, and that they would try to reduce it to 2000. That would make more colonels and lieutenant colonels necessary, granting that the total number remains the same.

Senator Fletcher. More in proportion.

The Chairman. Yes. Now, if a thing of that sort is done and you have a Signal Corps and Medical Corps and an Engineer Corps off to one side, but which, to keep pace, go hand in hand with the men on the combatant single list, it would be a God-send to the men in the Medical Corps, the Signal Corps and the Engineer Corps.

Col. Palmer. Well, that is true, but I think that efficient officers, unless they are given advanced promotions for some special cause, should be advanced at about the same rate in all the arms. I think it produces a better moral effect, and distracts attention from this organization question. Too many people are thinking about organization.

The Chairman. The tables of organization are very potent in the effect upon promotion. I think the War Department ought to have the right to change organizations inside the branch as it sees fit, but the change in the table of organization in the War Department which could be brought about by a stroke of the pen might mean the creation of 10 more colonelcies, 10 more lieutenant colonelcies, and 10 more majors.

Col. Palmer. You mean in that bill?

The Chairman. Yes.

Col. Palmer. I have not examined that feature of it.

The Chairman. You see, the National Defense Act contains tables of organization, which I do not agree with. This bill does not. It provides that the Infantry shall consist of so many officers and so many men, to be organized as the President sees fit, and I think that is the proper system.

Col. Palmer. It seems to me so, yes. I think one reason it has been difficult to get this single list adopted is that it is rather complicated when you come to the details of making out the list. But that can be worked out. It would obscure the general principle, to go into detail about it; but it can be and has been worked out.

Mr. Chairman, I have quite a little more to say, if it is of interest to you, in regard to the general staff and certain defects in its organization and functions.

I do not like to leave this question of a citizen army, the feasibility of a citizen army, without referring just a little bit more to the practicability of tests of efficiency that will make it possible to determine the proper places of officers, whether they happen to be in the Regular Army or in the citizen army. It is not purely a question of educational knowledge; it is a practical question.

For instance, in the case of the law, a man may come out number one in the class of a law school, but it will be impossible to determine in advance whether or not he is going to be a good lawyer; it may be that he will become a successful practitioner or judge, or it may be that he will be a mere pedant. His actual place is fixed during the practice of his profession. Now, in the military profession, a man may not have a chance actually to practice it in war until he has been in the service for 20 years, and it is little bit more difficult to determine.

But in France and Germany that is precisely what they determine in their peace establishment. That is the object of their annual maneuvers.

Wherever a country has an army that is substantially the same in peace and in war, such questions of fact can be determined.

It may be a little bit academic, but I would like to point out the principle of it in this way.

The military efficiency of an officer might be indicated by an equation: $E = AK$, in which E is his efficiency and K is his knowledge and A is a coefficient, and applicative coefficient determined by his character, his energy, and other practical factors.

Now, if you take a soldier like Napoleon, K is very high and A is also near its maximum value. In the case of a theoretical soldier, like our Gen. Halleck, of Civil War fame, K was probably as high as it was in the case of Napoleon, or nearly so, but his practical or applicative coefficient was very low, therefore his efficiency as a whole was low. Take a man like Forrest, a man so illiterate that he could not write an order; yet one of the greatest cavalry soldiers the world ever produced. In that instance K was perhaps very small, but A was exceptionally larger and what little he did not know he could apply. In his case the product, or total efficiency, had a large value. This fact has been very largely ignored in our military educational system. We develop K, or theoretical knowledge, as much as we can, but we do not put enough stress on A. We do not know whether we are going to produce a practical man or a pedant. In France and Germany they do not do that; they measure the product itself. When a man comes up to be promoted to a grade that would entitle him to command a battalion of infantry that is the one thing they measure—can he do that? It doesn't make any difference whether he is a philosopher or not or that perhaps some time later he may become a field marshal. What they measure is his capacity to command a battalion. It is perfectly feasible to measure that.

I can take a military map and write out a military situation indicating that there is a division of troops here and reports of an enemy off there, with certain other data pertaining to the situation, and I can give a candidate, we will say, for the General Staff, precisely the same intellectual problem—absolutely the same intellectual problem—that he would have to solve in time of war. He must answer it, not by writing an essay, but writing the precise orders that he would give in that situation.

That method was invented first by Frederick the Great, and was developed by von Moltke. In France it has been carried on by men like Foch. Through that method they have been able not only to train officers, but to actually measure them; they calibrate them and determine in time of peace whether a particular man can actually do the particular thing that is going to be required of him. And that is a very important thing to consider in regard to this citizen army.

The CHAIRMAN. In other words, these officers, before being promoted to a higher command, would be taken out and given an opportunity to show whether they could actually command a body of troops?

Col. PALMER. Absolutely; and purely as a matter of fact.

That leads me to one of the strongest points in this citizen army. I think when the conception first came to me, when I first began to work on it, the idea I had in mind was this: That it was the kind of an army that the United States must have. Whether the most efficient or not, it was the type fixed by our political institutions. But, as I have worked into it, I am inclined to believe that it is a powerful army in a military sense, the most efficient army in a military sense, because if you have universal training, those citizens who take the training, and are interested in military things, keep on and qualify for advancement from year to year so that what you really do in the end is to select military ability and leadership out of the whole twenty million people who would pass through that institution in thirty years. I believe that produces an army that is least militaristic in peace and also an army that is the most powerful in war. I think it would produce the most powerful army that the world has ever seen. As a member of the War Plans Branch of the General Staff, I believe that, under that system, we can create an army that would defend the United States against any combination of enemies, even assuming that our navy should lose command of the sea, and that the command of the sea should pass into the hands of a hostile combination. A citizen army of that kind would make our shores absolutely inviolate. Behind it we could deliberately develop our resources to meet any situation.

Senator FLETCHER. Would it take long to mobilize such an army?

Col. PALMER. You could mobilize it quicker than you could any other kind of an army. For example, take the plans for the defense of New York City. With an organized citizen army there would be one or more divisions actually living on Long Island. There would be two or more divisions in the city itself and others in New Jersey and elsewhere near the city. These troops would be living all their lives near their initial war positions. They would mobilize and be in their war positions within forty-eight hours, commanding every practicable landing place within striking distance of New York. During their peace maneuvers they would be practiced in the art of taking these positions. In my opinion, such an army would mobilize to meet the situation quicker than any other army that could possibly be devised, assuming, of course, that its men had had sufficient training that the officers and noncommissioned officers should get as a preliminary to promotion.

The organized citizen army would modify the conception of the Reserve Officers Training Corps as it exists under the present law. The Reserve Officers Training Corps is extremely important, as a part of the existing system. But if you have universal military training and an organized reserve army, most of the officers of that army would be raised from among the trained young men of each community, whether they go to college or not. It would not be necessary, inasmuch as all young men would receive military training, to have arrangements for close order drill and matters of that kind in the colleges. It would modify the system materially. The college would still have a place in offering certain elective studies to men who are qualifying for promotion in the military service, but it would take away any necessity on the part of the colleges to give a part of their time to rudimentary military drill.

I have heard it suggested, I think it was in Gen. Wood's testimony, that under universal training, young men in the colleges should be exempted from a part of the compulsory training. I think that would be a mistake, because I think it is just those young men who, for their own good and the good of their fellows, ought to go right into this democratic army.

I have noticed a number of references to West Point in the hearings. I think if an organized citizen army is our policy that the place for West Point would be a very definite one.

Under the system I have in mind, no young man would go to West Point until he had served his time in the ranks under this system of universal training. The cadets under that system would be the cream of the young men from the training camps, men who had already developed military aptitude. It would be no longer more or less of a pure accident as to whether a man was to go there or not; they would be men of predetermined aptitude.

Then, as now, the Regular Army being relatively small, its main function in peace times would become an educational one, and the place of West Point in the system would be that of a place to train trainers, a sort of normal school for the whole system, which would justify the highest kind of basic education.

So it seems to me that under that plan West Point while fulfilling its original aims would be brought into the closest contact with the people.

Senator CHAMBERLAIN. Before you leave that question of West Point, why would it not be possible, under some system of army reorganization and of a citizen army, for the colleges and universities to be training schools, with West Point as a postgraduate institution?

Col. PALMER. Well, I think a system of that kind could be worked out, but it seems to me that the citizen army itself would be the school for the training of the officers of the country; that it would be the school for the training of officers for the great war army. You will have to have a professional cadre, a professional training cadre, composed of men who are going to devote their lives to the military profession, and who would require this special training, and I believe that West Point itself would fill that bill.

Senator CHAMBERLAIN. In over 100 years they have not sent as many as 10,000 officers into the Army from West Point. They can not graduate enough men to do the work.

Col. PALMER. I do not know exactly what the present capacity is, but I think it might graduate three or four hundred a year. It would not be sufficient to furnish all the professional officers for the Army.

Senator CHAMBERLAIN. Some of the best officers we had in the war were young college men who have never been to a military institution?

Col. PALMER. Yes.

The CHAIRMAN. It is fair to say, however, that they learned the game from the West Point officers?

Senator CHAMBERLAIN. Yes.

Col. PALMER. Section 3 of the War Department bill contains proposed legislation affecting the General Staff. The hearings have been full of comment on and criticisms of the General Staff.

After the national defense act was passed in 1916, as a member of the General Staff, I was detailed to prepare some new regulations for the General Staff, in the light of the new law, and I had to dig in and find out just what a General Staff was before I could start on them. My ideas on that subject I suspected were vague, and I found that they were very vague when I began to go into it. I had to dig out and study the evolution of the institution in Germany, where it had gradually developed ever since about 1760, since the Seven Years War, and then I had to study the other question as to how an institution of that kind, designed for an autocratic government like Germany, could best be adapted to the kind of Government that we have.

I am perfectly satisfied that one of the principal causes for the confusion of thought in regard to a General Staff is that very few people know what a General Staff is. That is true in civil life; it is true in the Army; and it is also true in the General Staff itself.

One reason for the confusion is the fact that the German word "generalstab" when translated into English as "general staff" is an incorrect translation; it does not convey the same idea at all. It is generally supposed, because of that incorrect translation, that a General Staff officer is an officer who has a sort of general relation to every military activity, whereas, as a matter of fact, in the German Army and in the French Army he is a specialist of the most restricted type.

We started our general staff in 1903 and the British started theirs in 1904. The British recognized the foregoing fact, and in the literature, the documents, in connection with the establishment of the General Staff in Great Britain they pointed out that this confusion of meaning must be avoided. It was therefore suggested that it should not be called a General Staff at all, that it should be called an operations staff, a military operations staff.

Now, as an example of how restricted the meaning is in German—I am not a German scholar, but I have looked this up—the army General Staff in its modern form was started away back in the time of Ferderick the Great and has been developing all these years. The German Navy, however, did not develop until comparatively recently. When it got important enough for them to devise an agency for the navy corresponding to the General Staff in the army they did not call it the naval general staff, they called it the "admiralstab" or "admiral's staff."

That word "generalstab" should not be translated into English as "general staff." It should be translated into English as the "general's staff," or the "generalship staff," or the "tactical staff." The point is that just as a general needs a quartermaster's staff to assist him in certain matters of supply, a medical staff to assist him in certain matters in regard to the health of his command, so he needs a "generalship staff" or "general's staff" to assist him in the performance of his own peculiar function of leading troops in battle.

So in France and Germany General Staff officers are products of a special system of education and the subject matter of that education is precisely the same as the subject matter of the generals' education. The idea in Germany is to begin training these young men while they are young. They seek out those who have the tactical aptitude and train them as generals' assistants. They give them the precise training in higher troop leading and things of that kind that a general should have. The idea is that during their youth they are generals' assistants and that when they attain sufficient rank to command they will be generals in fact. For example, Marshal Hindenburg received that training in the German War Academy, and the fact that he had the tactical gift was determined in his youth as the preliminary qualification for the General Staff. He was trained all of his life to perform that function. As a captain or lieutenant he was on some corps commander's general staff. As he became older, he was on the great General Staff from time to time, and at another time he was a teacher in the General Staff college; but all his life he was practicing the profession of troop leading, of generalship.

So we have their conception of a general staff in connection with troops. They had a general staff with troops in the German Army for 60 years before they ever had a "Great General Stafl" or central general staff in Berlin; just as we had Army quartermasters, and a conception of what a quartermaster should be long before we had a quartermaster general in Washington.

It is important to realize the fact that a general staff officer is primarily an officer of special training, of a special professional type; and I think it is interesting to go back to the way the thing started.

At the close of the Seven Years War, Frederick the Great started a school for training young officers to perform this duty. He had developed himself in a method for accomplishing that end. It is described somewhat in Carlyle's History of Frederick the Great. I do not remember the exact quotation, but Carlyle points out Frederick's habit when going through the country, and seeing a piece of ground of a certain kind, of saying to himself, "I am in command of troops here, and if I were attacked by other troops from this direction, what should I do; what orders should I issue?" He began that practice before the battle of Mollwitz. Before his first battle he recognized that the question on the battlefield was a question of action, a question of what to do, and not a question of theoretical knowledge; that it was a question of practice. He kept that method up throughout his life. As he went on with it he developed his practical sense of tactical judgement; and out of that grew a great educational system.

The next step in the evolution of the idea was the thought that if this method of self-training in tactics was successful, it would also be an excellent means for training others. It is something like the case system in the law school, where a man is given a specific case to work out. We call this method the applicatory method. In France they call it the method of concrete cases. The student is required to solve a specific tactical problem and not to write an essay on it. He is required to make a tactical decision and to write the orders which should be written to meet that situation.

So Frederick the Great developed that idea in his educational system for young officers. It also has a further advantage, which is really the most remarkable thing about it. That is, it becomes a tactical measuring rod; it becomes a method of calibrating, by means of which a man who himself knows tactics can determine whether some candidate has tactical judgment or not. This is the method that Frederick the Great developed and for over 50 years before the great general staff was to meet in Berlin that system of education went on in Germany. It was training men to be general staff officers in the purely restricted sense that they were to be the assistants of generals in the performance of the generals' proper and strategical and tactical duties.

A General Staff officer in that sense is primarily a trained troop leader; he is a man who is trained in tactical values; and when he comes to coordinate other agencies or other services, it is purely in that direction that he ought to influence them. He should not do their business for them.

In that strict, original sense, the duties of these General Staff officers were to prepare fighting orders, to get intelligence of the enemy and make proper inferences from that intelligence, to conduct the training of troops and the development of tactical doctrine. A general can not do all those things alone, and these officers were to assist the general in doing the thing which was the general's peculiar problem. No officer could have this duty unless he was equipped for it, and all able officers were encouraged to aspire to it and to qualify for it.

Now, after the collapse of Prussia in the Napoleonic Wars, the old system broke down. Scharnhorst established "the Great General Staff" in Berlin, which would correspond to our War Department General Staff. The natural idea was that if it was desirable to have General Staff officers in Army Corps and divisions to look out for purely military functions there, it would be equally desirable to have men qualified to work on substantially the same problems for the Army as a whole. So in that way the great general staff at Berlin was formed.

I have frequently heard an analogy between a general staff and a board of directors; I think I have read it in these hearings. But the analogy is not carried far enough. It is a good analogy; but in a board of directors, as I understand it, a director does not interfere with any of the great industrial or technical activities of the corporation of which he is a director. He is an expert on just one thing, and that is the problem of profit. He coordinates that corporation, because he is acting on the whole proposition from the standpoint of its most important function; that is to say, the director is opposed to an item of expenditure even though very trifling, if it is a waste and affects the problem of profit unfavorably. But, on the other hand, if it is a question of the expenditure of a million dollars that will add to profit, he is favorably disposed to it. I think that is the real analogy with reference to the General Staff. The General Staff officer, if he is a real General Staff officer by training and belongs to that professional type, endeavors to coordinate the whole system in the direction of its primary function, that is effective fighting power. That is the only thing upon which he is supposed to be an expert.

If he is a trained General Staff officer, under the French and German systems, the tactical faculty has been determined and developed in him and that is the primary reason he is there. He may be much else, many other things may be required of him. If he is in the operations, or "G-3" branch, he is dealing almost purely with tactics. When he comes to "G-4" branch, the supply branch, he is dealing with something more than tactics, but he is always dealing with it from the tactical point of view. You put a trained General Staff officer in "G-4" and he will inform the supply services as to what they ought to supply in order to conform to the tactical plan; but if you put a former quartermaster in there, who is not a trained General Staff officer, he will think, no doubt, that he is put there for some reason or other, and the only way he can solve the problem is to do the quartermaster's business for him.

That is the thing, in my mind, that we have overlooked entirely in the development of our General Staff.

Senator CHAMBERLAIN. Well, did not the national defense act undertake to check measurably the disposition of the General Staff to go outside of what you conceive the General Staff duties are?

Col. PALMER. Yes; it did, but if you had prescribed that only trained General Staff officers could have been on the General Staff, the occasion for that legislation would never have arisen.

Senator CHAMBERLAIN. In other words, they would have known that it was not their duty to administer?

Col. PALMER. Yes, sir. If you should form a surgical hospital, and provide trained surgeons for it, it would not be necessary for you to make regulations that they should not interfere with the nurses or the apothecaries; because they would not want to do it.

Senator CHAMBERLAIN. But there was nothing in the act of 1916, and there was nothing in the General Staff act of 1903 that placed any check upon the appointing power, with regard to men who were suitable for General Staff officers——

Col. PALMER. That is true.

Senator CHAMBERLAIN. So that if there was any mistake made it was not in the law?

Col. PALMER. It was not in the law. I think the act of 1903 is one of the most perfect laws that we ever had on our statute books.

Senator CHAMBERLAIN. I think so, too. I read it only a day or two ago.

Col. PALMER. Yes, sir.

Senator CHAMBERLAIN. That was a perfect law, but the General Staff created under it began to go outside of the provisions and province of the General Staff proper, and the act of 1916, the national defense act, attempted to check that and to bring them back within the purposes of the 1903 act.

Col. PALMER. Yes; that is true.

I want to explain why that situation existed.

Senator CHAMBERLAIN. Yes, and if you can, suggest how it can be checked. I think it ought to be checked.

Col. PALMER. I have a specific recommendation for that when I come to it.

Senator CHAMBERLAIN. I would be very glad to have it. I did not mean to interrupt you, Colonel.

Col. PALMER. Before leaving this German institution, to which I referred, because that is where it evolved——

Senator CHAMBERLAIN. We are very much interested in it.

Col. PALMER. Von Moltke, when he came to the General Staff—I mean the original great von Moltke—regarded it as the principal duty to the General Staff to train General Staff officers. Even after he became chief of the General Staff he continued to be the principal tactical and strategical instructor of the German War Academy. He did that for two reasons: One was to see that the proper doctrine was imparted to these important officers that were being trained; but primarily I think so that he himself could determine which of them were General Staff officers in this strict professional sense.

For example, we have down in the library at the War College a set of von Moltke's problems—problems given to captains and lieutenants who were in the War Academy as candidates for the General Staff. In addition, we have comments on those problems taken from his shorthand notes. In one of these problems, he gave the candidates a map of Eastern Prussia, and told them that each one of them was in command of an Army corps and a Cavalry division stationed at a certain point on the flank of a possible advance of forces from Russia. He gave them that problem and all the information that might reasonably have been known to the commanding officer of that force, and he said, "What are your arrangements for tomorrow?" This situation was given as at 7 o'clock in the evening. In other words, they were not to write an essay on tactics or anything of that kind, but they were to put themselves in the place of a corps commander, make a decision and write at once the specific orders that should be issued to meet that situation.

Now, the remarkable thing about that was that those officers were young captains or first lieutenants. We have had a great deal of criticism in our own service sometimes because we have given problems that are a little bit too advanced for junior officers. It is significant that von Moltke was doing it there, and for a reason.

In his comments he mentions a number of defects in the solutions that were offered, and offered his suggestions as to how they were to be corrected, but he says "The majority of the young gentlemen have demonstrated that they are able to lead troops of all arms." And it was their capacity to do that, determined by him, that gave them their first provisional tour on the German General Staff. These young men were not given that test because he had the slighest idea of employing captains or first lieutenants to lead army corps, but because he expected to use them as assistants of the generals who were going to lead and train the army corps.

Education for the General Staff or Etat Major in France proceeds along practically the same lines. All candidates for the general staff attend the Ecole de Guerre for three years. The ascendancy of men like Foch, Petain, and Fayolle in the French army is due to the fact that they were the recognized teachers of tactics and the art of war in that school. The tactics of the whole French army have been formed by them. The corps commanders, division commanders, and most of the higher general staff officers have received their doctrine at their hands. They attained their positions because they had that doctrine.

In France the officer who successfully passes that course receives what is called a general staff brevet; he is borne on the rolls of the French army as a general staff brevet or eligible, and selections for the general staff are taken only from that list. The number of brevets, of course, is very much greater than there are places on the general staff, but members of the general staff can only be selected from that brevet list. Then when war comes that very large list is immediately available for the expanded general staff.

In my opinion, one of the most valuable features of that system is the fact that just as soon as an ambitious young officer enters the French army that eligibility list shows him the real goal for advancement. We have no criterion for advancement to our General Staff; there is no well-known way through which an ambitious officer can reach it.

When you consider the duties of the general staff in the field—and it should be understood, of course, that nobody should be on the War Department General Staff unless he is competent for General Staff duties with troops —you have to consider that a general, in order to make a command fight as a unit, has to give orders to thousands of men in the infantry, the cavalry, the artillery, the air service, the tanks, and the chemical warfare service. Those are the tactical elements. He also has to give instructions to the following administrative services: The adjutant, the inspector, the judge advocate, the chaplain, the provost marshal; also the following technical people: The engineers, the signal corps, the medical corps, the motor transport; also to the following supply people, the quartermaster, the ordnance, the transportation people, and so forth. He can not possibly do that himself, and the measure of his general staff is simply the body of officers necessary to assist him in giving the general's orders, and those orders only. Organization is facilitated in the first place by dividing up the different fighting services into organized units like divisions. Let us take the case of the commanding general of a corps with three divisions. He has those three divisions out in front of him to give orders to. He has all of these administrative and supply services in the rear that must function. He perhaps has only one or two roads up to his position, over which proper priorities must be determined; that is, the time when munitions must go up, another time when rations must go up; and another time when the wounded men must be evacuated. Obviously that road would become congested beyond belief in a very short time if somebody did not coordinate the activities of the operating services, at least to the extent of telling them what particular road they should use and when they should use it.

Now, I think I can illustrate right here as to how far the General Staff should actually operate. The operations section or the "G-3" section, gives the tactical or fighting orders. If it is a well trained army, with a well trained staff and well trained commanders, those orders will be extremely brief. They will simply give to each division commander his mission telling him what to do but not how to do it. They will be very brief. It is one of the first principles of proper General Staff practice, that the orders of the General Staff should not go any further than necessary to accomplish that object. But if the divisions are only partially trained; if the divisional staffs are improperly developed; if it is a new Army; then, as a matter of fact, you can not assume that all subordinate units will know just exactly what to do. In that case success demands that the operation orders should be amplified as much as necessay.

For instance, if I am a competent commander of a trained brigade and an order is given to me as to just how I would use my machine guns, that would not be a proper order; but if I am a partially trained brigader general, and my troops are only partly trained, it would be quite proper to give me such detailed instructions as might be necessary.

Coming back, then, to the services in the rear you have the same thing. There you have "G-4," the supply section of the General Staff, and its function is to give orders to the services in the rear. The same principle should apply here; no more interference in the operating functions than necessary. But there again you have the same proposition, that it may be necessary at times to go into a great deal more detail.

Now, when we formed our General Staff we were in a different position from the French or the Germans.

Senator CHAMBERLAIN. You mean over there?

Col. PALMER. No I mean the formation of the General Staff in 1903. The British formed theirs in 1904, and we formed ours in 1903. We had the problem of forming a General Staff in a country where there were no trained General Staff officers. That is a good deal like forming a college of physicians and surgeons in a country where there are no doctors. The British recognized that fact. Their literature shows that, and they pointed out that one of the first functions of this new General Staff must be the education of general staff officers and the establishment of eligibility for General Staff. Men like Haig, Robertson, and Wilson are products of that system.

The problem was a little bit simpler for the British, because their General Staff had that one function of general staff duty. Our problem was a little more difficult because the act of 1903 created two new agencies and not just one. The act of 1903 created a General Staff, and it also created a new supervising agency in the War Department, an office of Chief of Staff which was not included in the British system at all.

If that act of congress had merely created a General Staff, we might like the British, have taken time to solve the first problem of the General Staff. Namely the development of a personnel, trained for General Staff duty with troops. Having that personnel and the general educational system necessary to produce it, the coordinating problem would largely have solved itself. But it is safe to say that probably nobody on our first General Staff panel really knew what a General Staff was. They probably all felt, however, that they were ready to assist the Chief of Staff in supervising the Adjutant General and the Quartermaster General and the other Bureau Chiefs. They were ready to coordinate without ever realizing that they did not posses the fundamental and specific tactical training which is the sole legitimate basis for General Staff coordination. In short through the popular mistranslation of a foreign term they began to busy themselves as a "General" Staff and not as "generalship" staff.

Senator CHAMBERLAIN. Perhaps they thought that they had nothing to do unless they did that.

Col. PALMER. Quite likely. That was very natural under the circumstances.

If they had really known what the professional type was and how important it was to create it, they must have accepted that as the first problem before them.

In other words, our General Staff was formed not to perform functions that were already being performed, but to perform functions that were not being performed at all under the old system. They did not get started at that right away, and the consequence of the situation was that we had no General Staff with troops; we did not have any organized bodies of troops and did not have any conception of what the General Staff's duties with troops were. We had no specific eligibility for the General Staff, and the conception was that what we wanted on the General Staff was merely able men. Well, we got them, probably the ablest group of officers in the service, but that did not fill the bill. What was required was a particular kind of ability. No amount of legal or architectural skill or ability will qualify a man to practice surgery. And no amount of ability as an artilleryman or infantryman or cavalryman will qualify a man for the General Staff. That was the situation when our General Staff was founded.

However, not very long after that, it happened that a revolution took place in our school system. We had what was called an Infantry and Cavalry School at Fort Leavenworth. Before the Spanish-American war it was an excellent school. That school was resumed in 1903, and started very much along the old lines of giving a great deal of academic knowledge and a great deal of information on military matters, up to 1906. About 1906 Maj. Morrison, now Maj. Gen. Morrison, introduced out there in our school a system precisely the same, with respect to the method of tactical instruction, that von Moltke had developed; that is, specific instruction for the tactical duties of the General Staff, by the method of concrete cases. It was absolutely revoluntionary in our service, and very few of our officers realized it.

We had that school out there and, in theory, officers would go there for two years, and if they passed the qualification stage they would come to the War College here and take a course, which was really a probationary tour on the General Staff. Under that plan we had an educational system very much, so far as practical efficiency goes, the same as the one von Moltke started.

Now, these new tactical methods, these methods of practical education and calibration were put into effect by Gen. Morrison, a man whom I regard as one of the greatest geniuses I have ever known, a man who is not well known outside the Army, but who to a large extent has put a new soul into our military service.

From that time on, officers graduated from there, after two years of practical test as to their capacity to solve tactical problems, and upon graduation recommendation was made as to whether or not they were qualified for General Staff duty with troops; they were recommended as comptetent to be division commanders, or perhaps chief of staff of a division in the event of war. But that was never recognized at all as essential in our practical determination of General Staff eligibility.

In 1916, when I was detailed to draw new regulations for the General Staff, I tried to get a regulation to that effect put in. I fought it out, but without success.

There were 51 officers on the General Staff at that time. Of these one officer, and one only had had the course of the Staff College, with the final course at the War College. There were six or seven of us who had had the preliminary two years tactical grounding at the Staff College, but had not had the final course at the War College. I think there were 10 or 11 who had the finishing school without the proper preliminary training. The remainder, a great majority of all, had had no General Staff training at all.

Now, that was the situation before the war. We had not done what the British regarded as essential and necessary to be done, and that was to establish a system of General Staff eligibility, and I think that accounts for a great many of our difficulties. Fortunately, however, there was a considerable number of officers in the service who were trained and available for such duty.

Senator FLETCHER. How was the General Staff selected at that time?

Col. PALMER. Selected as it is now, by boards of general officers who, in the absence of any specific criterion, selected generally able officers. They always have selected able officers; but, because they did not understand the real requirement, they did not pick out the specific type.

But when we went over to France, Gen. Pershing recognized and carried out the correct policy just as far as he could.

Senator CHAMBERLAIN. That is the French policy?

Col. PALMER. Yes; that is, wherever he could, he employed trained General Staff officers for General Staff duty. There were not enough to go around. There were a great many very able officers, who were sent over there for Staff duty that had not had that training, but wherever he could he utilized trained officers and trained just as many as he could.

Senator CHAMBERLAIN. Where could he get them?

Col. PALMER. There were probably a couple of hundred of them trained efore the war.

Senator CHAMBERLAIN. That had had General Staff duty or training?

Col. PALMER. Yes, officers who had had General Staff training along tactical lines.

Gen. Pershing utilized these officers, as far as he could. In my own section of the General Staff, the Operations Section, so far as I could I got officers with that training, officers that I knew had been calibrated and tested for that duty. Then just as soon as we could we supplemented that supply by establishing a General Staff School at Langres, where we had the advantage of the assistance of British and French General Staff officers. Of course, we could only give these students a three or four months course and could not give them full General Staff training. We had to specialize instead of training them for General Staff duty as a whole. We had to take a man whose record showed that he might have aptitude for operations and train him for "G-3."

Senator CHAMBERLAIN. That was what ought to have been done here before the war, according to your theory?

Col. PALMER. Certainly. In my opinion, it was that policy more than anything else that made the tactical and strategical success of the American Expeditionary Force possible. To my mind it was due very largely to that, that within a little over a year after our first division arrived in France, there was a great American front; that there were two major American offensives and that American commanders with American staffs actually led those large bodies of troops in battle.

Senator CHAMBERLAIN. You think they could not have done it in the condition they were when they first went over?

Col. PALMER. I do not think it could have been done if Gen. Pershing had selected his general staff in the promiscuous and unscientific manner prevalent in the United States before the War.

In the latter part of August, 1917; I think it was the 19th of August, I went up to the French front north of Verdun. I went up with Gen. Pershing and we were the guests of Gen. Petain. I was there when the French made that attack through which they recovered the position of Mort'homme on the hills just northwest of Verdun, on the morning of the 20th of August. On the evening of the 19th I was present when the chief of staff of the French Second Army was receiving reports from the chiefs of staff of the different army corps as to the progress of demolition and the progress of artillery work up to that point, and giving final instructions and modifications necessary for the attack, which was to begin at daybreak. When I looked at the elaborateness of the system, at the business methods required, and the large number of highly trained and specialized men that were necessary to make it work, it was almost appalling to me to conceive how we could ever do the same thing promptly with the limited trained personnel that we had.

On that trip I was present at a number of conversations that Gen. Petain had with Gen. Pershing; and, in considering and weighing the contribution that America might make to the war and the difficulties that confronted us, the French commander expressed more concern over our lack of trained General Staff officers than any other thing.

Gen. Pershing had already completed his plans for starting this General Staff training and Gen. Petain was more than ready to assist him in every way. Now, while we had a very limited number of trained General Staff officers, we had a good many more than the French realized, so that it was not necessary to simply let them lead us by the hand. We were able in a few months to take the additional doctrine that they had, and in a very short time we were running our own schools.

Now, that was in August of 1917 and in October of 1918, just a little over a year later, I went up to that same front, just before I reported to command my brigade and I heard an American chief of staff of a field army, in pretty nearly that same terrain, giving tactical directions to three American chiefs of army corps, to take such and such a place the next day. They were all men that I knew and they were all men who were graduates of our staff college at Fort Leavenworth—all men who had been tried out for their present duty and recommended for it and calibrated for it—men that there was every reason to believe could deliver the goods, and they did.

Now, sir, in my opinion, that represents the absolute fundamental requirement for an efficient General Staff. I believe a General Staff is an absolutely indispensable agency, and I believe if it is composed of properly trained General Staff officers that it will necessarily function. I do not believe that any amount of prohibition or injunction will make it function unless that preliminary condition is fulfilled. I know of many cases where

General Staff officers have gone beyond their proper sphere in dealing with troop commanders and services; but I do not know of any instance where it ever occurred that it could not be traced back to the fact that the man who did it was not a trained General Staff officer. That has been my experience. Trained General Staff officers do not want to do it. The 1903 act is a brilliant and beautifully worded law, ideally adapted to accomplish its intent. In that law the phrase "informing and coordinating" is used. It has been my experience that if the informing part is properly done, the coordinating part generally takes care of itself. And that is the great function of the General Staff.

Finally, I believe that the following rules must be adopted if you are to have an efficient General Staff:

(*a*) No officer should be detailed to the General Staff until after specific training for General Staff duty and official determination of capacity to perform the duties of a General Staff officer with troops. The test of eligibility should specifically include a determination of the officer's tactical judgement and his ability to prepare sound tactical orders for the maneuver and combat of a division or greater force of all arms. A list of all officers eligible for detail to the General Staff under these conditions should be published in orders annually and the fact of eligibility should be published in the annual army register under the name of each eligible officer.

(*b*) The list should include the following officers:

(1) Those graduates of the Army Staff College prior to July 1, 1917, who upon graduation were specifically recommended as qualified for duty as commander or chief of staff of a division or greater force of all arms.

(2) Those graduates of the Army War College prior to July 1, 1917, who upon graduation were specifically recommended as qualified for duty as commander or chief of staff of a division or greater force of all arms.

(3) Those officers who have demonstrated by their actual service during the recent war, that they are qualified for duty as commander or chief of staff of a division or greater force of all arms.

(4) Those officers who hereafter upon graduation from the General Staff School are specifically recommended as qualified for General Staff duty with troops on active service.

(*c*) Boards of general officers detailed to select officers for the General Staff should be composed only of general officers who themselves are eligible for detail to the General Staff.

The provision of such a list would not only assure competent personnel for the General Staff, but would establish a clearly defined avenue to the General Staff open to all ambitious officers who desired to qualify for that duty.

Nothing could be done that would have a more stimulating effect upon the ambitious young officers of the Army. It would establish a clear goal for professional aspiration open to all from the moment of entry into the service. It would produce a greater number of general staff eligibles than would be required for the peace establishment of the General Staff and would furnish a means for the immediate expansion of an enlarged General Staff in time of war. I think that the number of officers that would come under that classification now would be approximately 250, and that our existing system of military education would probably add 30 or 40 to the list each year. It is fortunate now that it can be done without putting it purely on an academic basis. A credit should therefore be given to those officers who during the war have performed that duty and have performed it well.

Senator CHAMBERLAIN. Can you tell the committee how the selections for the General Staff have been made since 1903; what the consideration has been that has led to the appointment of officers on the General Staff?

Col. PALMER. Well, I have no doubt that the boards have been very conscientious in their efforts to find able officers. There have been careful examinations of the records of prospective general staff officers and the boards have generally selected officers that they know to be efficient. But there has been no established criterion such as exists in all other modern armies.

Senator CHAMBERLAIN. In other words, they have not had in mind the fundamentals of which you speak?

Col. Palmer. They have not.

Senator Chamberlain. Do they have them in mind now?

Col. Palmer. I think so, because in the last list the great majority of them would have been eligible for General Staff duty under the rules I have just indicated. But I think it ought to be mandatory. I believe it ought to be known to the service and known to the country.

Senator Chamberlain. You have doubtless seen the opinion of the Judge Advocate General, as well as the opinion of the Secretary of War, overruling the opinion of the Judge Advocate General, in 1916?

Col. Palmer. I have read them, Senator, but it was some time ago.

Senator Chamberlain. I rather incline to the opinion, from my recollection of those two opinions, that the Secretary of War in his opinion did not have the idea of a General Staff which you have so plainly explained to us today.

Col. Palmer. I think it is quite likely that he has not. I think it is not generally known in our country, Senator; it is not generally known.

Senator Chamberlain. Is there any way to define in a statute what the qualifications of appointees for the General Staff should be, and is there any way to ascertain those qualifications when once they have been prescribed?

Col. Palmer. Both are perfectly feasible. There is no doubt about it.

Senator Chamberlain. There isn't any bill before us now that does that.

Col. Palmer. No, sir.

Senator Chamberlain.Do you think it would be a wise policy now to practically re-enact the General Staff act of 1903, eliminating a Chief of Staff for the future?

Col. Palmer. No, sir. I am afraid I ran the risk of being misunderstood on that, Senator. What I meant to say was that two new agencies were formed in 1903, but that the primary and more important agency was overlooked for a long time. I think we ought to have them both and that the law as it stands is ideal. There ought to be a policy forming or planning agency in the War Department, as contemplated by the second section of the act, and there ought to be an executive agency to supervise the execution of that policy as provided in the fourth section of the act. Now, if all the officers on the General Staff were trained General Staff officers, all the causes for any shortcomings that there might have been in the past would be removed.

Senator Chamberlain. Is there any officer, either in the British or French or German general staff that corresponds to our Chief of Staff?

Col. Palmer. Yes, in the French system but not in the original German system.

Senator Chamberlain. Does he have any functions of command?

Col. Palmer. You mean the French chief of the general staff?

Senator Chamberlain. Yes.

Col. Palmer. I think he does. Gen. Foch occupied some such position before he was placed in supreme command of the allied armies.

The Chairman. Early in the war he became an army commander.

Col. Palmer. But I think just before he was made supreme commander he was on duty at the French Ministry of War in a position that corresponds very closely to the position of Chief of Staff. That point, Senator Chamberlain, depends on the political organization. In Germany the problem was a very simple one. There was a Kaiser, who was a soldier himself, the War Lord. Now he had under him three practically independent agencies; he had three problems; first to determine what to do, second, to provide the matériel and the means of executing that policy; and third, to provide proper leaders to carry it out; a General Staff to determine what to do, a Minister of War to provide the army, the money and the men, and a Military Cabinet to select the higher commanders. The military cabinet had the function of selecting army and corps commanders and the higher agents to carry the determined policy into effect. So in Germany the War Department and the General Staff were entirely separate. The Chief of the General Staff was coordinate with the minister of war. When they prepared for the Austrian war in 1866 von Moltke was the Chief of Staff and von Roon was the War Minister.

The idea was that von Roon prepared the sword and von Moltke wielded it. That is possible in a system where the head of the government is the military commander, because he is the coordinating agent himself. But when you come to a form of government in which you have a civilian minister of war who is responsible to the civil authorities for the efficiency of the military establishment, it seems to me you have got to connect up everything under him; that makes it necessary to have some military agent through which he acts. If he has a properly formed general staff with four sections, very much as the French have it, I think it is an ideal system for us, and at any rate that is the thing——

The CHAIRMAN. What do you think the proper function of the Chief of Staff is under an ideal system in this country?

Col. PALMER. I think when it comes to a question of military policy, when it comes to a question of planning the national defense, and the plan is of such a nature that it has to be transmitted to higher authority and ultimately to Congress in order to be carried into effect, that that part of the General Staff that is charged with planning is really a deliberative body, and that the Chief of Staff is then a presiding officer and not a commander. When it comes to the execution of an approved policy I think the executive function of the Chief of Staff should be absolutely like any other function of military command. When it is a question of bringing a policy to you prepared by an agency which you have created in order to form that policy it looks to me like the Chief of Staff is essentially in the position of a presiding officer.

For example, if I am in command of a regiment of infantry, so long as I act according to regulations and orders of higher authority, the policy of that regiment is my policy, and that is proper and right; but if I am the senior officer of a deliberative scientific body, instructed to prepare a recommendation for a higher authority, I am not the commanding officer in that sense. In other words, you can not apply the principle of command to both processes. In that event—and I will take my own branch of the General Staff, dealing with national defense plans, if a project is brought to me that I do not agree with, I call the members of the branch together and talk it over with them. Frequently that will result in a correction or amendment. Perhaps they will continue to be a difference of opinion between me and the officers who prepared the plan. In that event I do not believe that I have any right to order them to accept my view. I do not believe I have any right to forward my own opinion and suppress theirs, but I do have the right and duty to forward their view with such adverse comments as I choose to make. I do not think you can arrive at a scientific determination of policy in any other way.

The CHAIRMAN. On page 6 of the War Department bill will be found a paragraph prescribing the duties of the Chief of Staff. Among other things it says he shall be charged by the Secretary of War with the planning, development, and execution of the Army program. As I understand it, you believe the General Staff should be charged by the Secretary of War with planning the Army program?

Col. PALMER. Yes, sir; in so far as it is a question of military policy that would have to go to higher civil authority for approval before it can be put into effect. I think the paragraph you have just cited would destroy the institution created in the act of 1903 and replace it by another institution entirely different in kind.

The CHAIRMAN. It occurred to me that it is exceedingly important language, and it refers merely to the Chief of Staff. That practically makes him what you think the General Staff ought to be.

Col. PALMER. The act of 1903 made the General Staff the planning agency. This new language would make the Chief of Staff the planning agency. Now a little bit further down the language of the act of 1903 with regard to the duties of a General Staff is retained, except that new words are inserted.

Senator CHAMBERLAIN. That changes the whole basis of it.

Col. PALMER. It says: "The duties of the General Staff Corps," and then come the new words inserted "Under the direction of the Chief of Staff," and then it continues "shall be to prepare plans for the national defense," and so forth. In other words, the passage of that law would transfer the planning function to the Chief of Staff, and would leave to the General Staff only the ministerial function of working out the details.

Senator Chamberlain. I do not think that is right.

Col. Palmer. I do not think that power should be given to any individual. I do not think it was intended in the law. I do not think it is essential to the proper operation of the General Staff.

The Chairman. Now that we are on that language, Colonel, why not discuss it rather thoroughly. On the bottom of page 5 will be found a portion of section 3 which prescribes the duties of the Chief of Staff and later of the General Staff Corps. It reads as follows:

The Chief of Staff, under the direction of the President or Secretary of War, shall have supervision of all agencies and functions of the military establishment and shall perform such other military duties, not otherwise assigned by law, as may be assigned to him by the President.

Have you any criticism to make of that language?

Col. Palmer. I think the wisest thing would be to adhere to the 1903 act. I think that is ideal legislation for a perfectly efficient General Staff, except in so far as it prescribes the number of General Staff officers and makes the Chief of Coast Artillery an ex officio member of the General Staff.

Senator Chamberlain. Would not that language, which the chairman just read to you, practically turn over the Army to the Chief of Staff?

Col. Palmer. Yes. It would turn over that function which was not heretofore turned over to him, the planning function.

Senator Chamberlain. Which practically gives him control over the whole army——

Col. Palmer. The act of 1903 has quite different language. The act of 1903 gives the Chief of Staff supervision of the different branches of the Army and of certain specific departments. This is rather noticeable to me, the order of statement is different. I do not know whether that carries any significance in the law or not, but in the act of 1903 the first section creates a General Staff Corps, and the second section defines the duties of the General Staff——

The Chairman. You mean the Chief of Staff.

Col. Palmer. No; the General Staff comes first in the act of 1903 and the Chief of Staff does not come in until the fourth section, Mr. Chairman. In the act of 1903 the General Staff is defined; then its duties are prescribed with reference to the plans for national defense, then in section three the number of officers on the General Staff is brought in, and it goes on down in section four, where the Chief of Staff is given the supervisory function. I have always supposed it meant that when it came to the execution of policy that he was the executive agent to issue orders in the name of the Secretary of War. There is a big problem that comes in here and that is where our General Staff differs from the German General Staff. The German General Staff was designed to inform and advise just one man who was himself a military man. Our General Staff is very much like the British General Staff, and was formed primarily to advise a civilian Minister of War, and through him, the national legislature. It is quite a different problem.

Now, when it comes to the question of determining a policy, the whole situation is different from a question of command. Whether a national policy is sound or not, is a question of its intrinsic merit and not a question of authority. It is a good deal like a theorem in geometry, in that it does not make much difference whether the best solution is made by a lance corporal or a field marshal. When it comes to the test it has to be determined on its merits. No question of national policy is ever settled until it is settled right.

The Chairman. Now, we want to get your recommendations and opinions on the rank of officers on the Staff.

Senator Fletcher. How large a General Staff do you recommend for peace times?

Col. Palmer. I should say that the general method of determining the strength of the General Staff is correct in this bill. This bill provides, if I remember correctly, for 217 General Staff officers, 120 of them with troops; that is, 50 of them are on duty with corps staffs and the remainder of the 120 on duty with divisional staffs, leaving about 97 for the War Department General Staff.

Senator CHAMBERLAIN. What would they do here in peace times?

Col. PALMER. In the War Department?

Senator CHAMBERLAIN. Yes, those who are on duty here?

Col. PALMER. They have a great many important duties. They have the problem of keeping the Army prepared for war, supervising its training, coordinating its supply system, and so forth.

Senator CHAMBERLAIN. In an army prepared for defense, do you think the Chief of Staff or the General Staff, should direct the chiefs of bureaus in the purchase of supplies, etc.?

Col. PALMER. I do not think any General Staff officer, except the Chief of Staff, should direct the chiefs of bureaus.

Senator CHAMBERLAIN. Would it be within the functions of the General Staff to direct the bureau chief as to what he was to do or simply advise him as to what the staff had adopted as a policy?

Col. PALMER. I think it is perfectly proper for the Chief of Staff to give whatever directions are necessary in order to carry out an approved policy, Senator, but I think that if the bureau chief is correctly and intelligently informed as to the plan to be followed in order to carry out a policy, that that will generally be sufficient.

Senator CHAMBERLAIN. You do not think the Chief of Staff should be an administrave officer?

Col. PALMER. I think he must be to a very large extent; I think so when it comes to carrying out a policy that has been approved. For example, if you should create a citizen army and that should become the military policy of the United States, I think the Chief of Staff—after the regulations covering it are prepared and approved by the President—would have to be the executive officer for carrying that policy into effect.

Senator CHAMBERLAIN. You mean for the President?

Col. PALMER. Yes.

Senator CHAMBERLAIN. But not directly in connection with the bureau itself. What I am trying to get at is this: You will remember the restriction which was undertaken to be placed upon the General Staff by the act of 1916?

Col. PALMER. Yes.

Senator CHAMBERLAIN. The intent and purpose of that restriction was to prevent the General Staff or any of its agencies from undertaking to control the administrative bureaus or service bureaus, and don't you think that restriction was proper?

Col. PALMER. I do not think you can apply any hard and fast rule there. I think the evil, then, you speak of has occurred, and I think it has generally occurred, because the General Staff was not composed of trained general staff officers.

Senator CHAMBERLAIN. Men who did not understand the General Staff duty thoroughly?

Col. PALMER. Yes, sir.

The CHAIRMAN. Of course, under our present system, the Secretary of War, with, of course, the President to oversee it, decides upon the Army program and the General Staff is to advise him, to investigate and study, and keep him informed.

Col. PALMER. I should say——

The CHAIRMAN. Of course he can disapprove in whole or in part any of their recommendations.

Col. PALMER. I believe you said, Senator, that it is the duty of the Secretary of War, for the President, to decide upon the Army program?

The CHAIRMAN. Within the limits laid down by Congress, of course.

Col. PALMER. That is what I mean, because the determination of an Army program depends very largely in the beginning on congressional action. And now I think that is what is referred to here as the planning function of the General Staff as a whole, the determining of what that program should be for transmission to Congress.

The CHAIRMAN. Yes, with such comment as the Secretary of War might see fit to attach to it.

Col. PALMER. Yes, of course.

The CHAIRMAN. Those are the broadest problems that are to be considered by the General Staff, but there are lots of other problems in the Army itself which would not in the ordinary run of events come before Congress. For instance, this bill, I think, quite properly does not attempt to prescribe the strength of an Infantry regiment; it simply prescribes what shall be the total number of Infantry officers and soldiers. Is it not in the duty of the General Staff to study the question and organize Infantry units?

You system there is such that I suppose when recommendations go through the Chief of Staff to the Secretary of War, the Chief of Staff, as those recommendations or studies pass over his desk, I assume, has a perfect right to make comments on them, either favorably or unfavorably.

Col. PALMER. Yes.

The CHAIRMAN. The Secretary of War must decide whether to accept the study or recommendation as it stands, with such amendments as he sees fit to add to it.

Col. PALMER. Yes, unless it is a question that has already been settled by a predetermined policy. I do not think it would be necessary with a question of that kind, if the Secretary of War has already approved the general policy with reference to one of those matters, that all matters arising under that policy should be referred to him. They would be decided by the Chief of Staff, because he already has the decision of the Secretary of War on those points or on the policy governing them.

Senator FLETCHER. In other words, he follows a precedent that has been established?

Col. PALMER. Yes, sir.

The CHAIRMAN. Have you any further criticisms to make of the language used in this bill describing the powers and functions of the Chief of Staff and the General Staff Corps?

Col. PALMER. The point I made with respect to eligibility is, I think, a very important thing. I would like to refer to the number of officers specified in the War Department bill. I think the total should be specified, but I do not think a General Staff law should specify the numbers in each grade so definitely. For example, this bill specifies 10 general officers, 41 colonels, 73 lieutenant colonels, 89 majors, 17 captains. I think there should be a provision that if there are not 10 general officers available who are really eligible for duty on the General Staff, that eligible men should be taken from the lower grades; that if there are not 41 colonels who are really fit for duty on the General Staff, that proper and eligible officers should be taken from some other grade. In my opinion we do not want anybody but trained General Staff officers on the General Staff. If you have untrained officers on the General Staff, the higher rank they hold the more harm they will do.

The CHAIRMAN. Of course, to make your suggestion effective we would have to insert in this bill the eligibility clause which you have been discussing.

Col. PALMER. Yes, sir.

Senator SUTHERLAND. Then you would have to put in a proviso where these specific numbers are provided for?

Col. PALMER. Yes.

The CHAIRMAN. As I understand you, you think the language of the act of 1903 plus the language prescribing eligibility is sufficient?

Col. PALMER. Yes, sir.

The CHAIRMAN. Then whatever number is requisite could be decided upon?

Col. PALMER. Yes.

The CHAIRMAN. As I gather your idea, you think the language commencing near the bottom of page 5 and on page 6 would be unnecessary?

Col. PALMER. I think that language would completely modify the original General Staff law. I do not believe in it.

The CHAIRMAN. Particularly that phrase, "under the direction of the Chief of Staff."

Col. PALMER. Yes, particularly that question of planning for the national defense.

The CHAIRMAN. The language that the Chief of Staff shall be charged by the Secretary of War, with the planning, develping, and so forth of an Army program?

Col. PALMER. Yes. Of course, the language is a little vague as to what an Army program means. I do not know just what it means. I think the language of the act of 1903 is a great deal better language.

Senator FLETCHER. Did you say you had prepared something to substitute for this clause.

Col. PALMER. No, sir.

Senator FLETCHER. I thought you said at the outset that you had something prepared?

Col. PALMER. I said I had a specific recommendation to make with reference to the General Staff, and that is that it should be restricted to officers who represent that professional type, as a matter of fact.

Senator FLETCHER. You have not anything prepared on that subject, have you?

Col. PALMER. I have not here, no, sir.

The CHAIRMAN. We should be very glad to have you prepare a section embodying your views on that.

Col. PALMER. This is on the question of military expenditure. There is an economic side to it. If you take a Regular Army of the old type, the cost is generally computed as unproductive; there is no return on it, but if you take the cost of the citizen army, where all the people have adequate training, you get an economic output. For example, in such an army as proposed in the Kahn-Chamberlain bill, the foreigners, the non-English speaking foreigners, would receive an advantage which they would carry back into civil life. All men would have certain pathological tendencies discovered early and corrected; they would be improved in health, and they would have better instruction as to personal hygiene. There would be the substitution of many good habits for many bad habits. The idea of the development of leadership in a military sense would reflect back into civil life to a certain extent. The system would have a nationalizing infleunce. There would probably be a reduction in the cost of prevention of crime and for dependency. Of course, a good many of these things are imponderable, but I think they undoubtedly add to the economic value of men.

Now, if the average man in that system has his productive power increased only 30 cents a day, by the time the system is in operation for 40 years this would mean an increase in the annual productive power of over two billion dollars a year. If the average individual received a benefit of only 30 cents a day the annual economic gain would be more than three times the cost of the whole Military Establishment. If you take an army of the professional type, with any given amount of military power, the cost is greater and the economic output on the other side is very much reduced.

The CHAIRMAN. In fact, when they have stayed in the service beyond a certain useful period, there economic value would begin to decrease?

Col. PALMER. Yes.

The CHAIRMAN. The enlisted men, if they go on reenlisting, would pass the age beyond which, when discharged, they would produce effectively in civil life.

Col. PALMER. I mean the amount expended on universal military training would be very much less than the economic advantage that would result from it as expressed in dollars and cents.

I think that is all.

But there is one other feature upon which the efficiency of the General Staff depends. General Staff officers should view military questions from the standpoint of all arms combined. No officer should be on the General Staff merely as a representative of the interests of a particular arm. This implies that the General Staff should exercise a judical function. For this reason each combatant arm should have a chief or director in the War Department, but not on the General Staff, charged with presenting the ex parte view of his own arm. At present we have no chief of Infantry or chief of Cavalry. These officers should be provided by law.

The CHAIRMAN. We are very much obliged to you, Col. Palmer.

PROFESSIONAL NOTES

On Pyrostatics[*]

Translated by Col. Frank E. Harris, C. A. C., Inspector General

EDITOR'S NOTE.—In preparing the translation of this valuable article for the JOURNAL, Colonel Harris has also furnished a note showing the derivations of all the important equations in the article. It would be desirable to include Colonel Harris' note herewith, but the limitation of space forbids. However, it will be kept on file by the Editor, and is available for loan to any JOURNAL reader sufficienty interested to request it.

Introduction

I. The "Rivista di Artiglieria e Genio," in its recent issues (†) published some very interesting articles on the *combustion of powders in closed vessels* and Regii, in these articles, has been good enough to recall our works on this subject.

Since the publication of our first work (1908), the question of the fundamental bases of Interior Ballistics has not ceased to be studied, (‡) In Germany, the Krupp's adopted the general ideas which had guided us, and particularly, the conception of the indeterminate form function $\varphi(z)$; in France, on the other hand, Naval Artillery Engineer Sugot, in a series of articles inserted in the Memorial de l'Artillerie Navale, then in his Cours de balistique, has perfected the theory and made it readily applicable to the fire of all pieces by computing all the numerical tables necessary for the application of the method called: CH. S. The complete exposé of the theory, under the form now acquired, necessitated very considerable developments.

It nevertheless appears possible, since this question has been specially treated in the "Rivista," to give with some detail the new outline which we have adopted for the exposition of the laws of combustion of powders in closed vessels, that is, pyrostatics.

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[*] We are glad to publish in our "Rivista" this most valuable article of the eminent French ballistician, General P. Charbonnier, head of the "Mission d'études de l'artillerie" and of the "Mission balistique des tiro aerieno," who is well known to our artillery officers. The article, sent as an homage to our artillery experts, sums up the theory of pyrostatics, which was recently developed by the able author in a work just finished but not yet published.
N. d. D.

[†] See Rivista, 1917, Vol. III, pp. 5 and 170.

[‡] 1° Charbonnier, Ballistique Intérieure. (E. S. I vol., 1908).

2° Naval Artillery Engineer Sugot: 1. Les formules differentielles des poundres d'aprés la theorie balistique du Ct. Charbonnier. (Mém. Art. Nav. 1909). 2. Sur la poudre et le canon de puissance maximum. (Mém. Art. Nav. 1909). 3. Les formules de la theorie Charbonnier. (Mém. Art. Nav. 1913). 4. Note sur l'etablissement d'un projet de bouche a feu. (Mém. Art. Nav. 1913). 5. Methodes de recette et de tarage des poudres. (Mém. Art. Nav. 1913). 6. Cours de Balistique de l'Ecole d'Application de l'artillerie Navale. (Unedited, 1917.)

3° D.r. Ing. Schmitz, Recent experiments of the Krupp Company on the subject of Interior Ballistics ("Artilleristische Monatshefte," 1913 - 1914. Translation. Mém. Art. Nav. 1915).

4° D.r. Bollé, On the Present Status of Interior Ballistics. (Kriegstechnishe Zeitschrift, 1914).

TRANSLATOR'S NOTE—By Pyrostatics is meant the science which treats of the laws of combustion of powders in closed vessels.

II. Let us first recall the form under which the first fundamental law of pyrostatics presents itself. The fundamental law which is expressed by Noble & Abels' formula:

$$P' = f \frac{\Delta}{1 - \eta \Delta}$$

is only applicable to the maximum pressure P′. But, for the study of Interior Ballistics we must know the value of the pressure P during the entire course of the combustion, that is, when a *fraction z of the charge has been burned.*

We immediately arrive at the generalization sought by adopting the theoretical interpretation of this formula based on Sarrau's ideas.

At the instant the fraction z is assumed burned, a weight ωz is converted into gas and a weight $\omega(1-z)$ is still unburned. If δ is the density of the unburned powder, the volume occupied by the weight $\omega(1-z)$ is $\frac{\omega}{\delta}(1-z)$, and this volume is to be substracted from the volume c′ of the closed vessel. Then, in this reduced volume

$$\left[c' - \frac{\omega}{\delta}(1-z)\right]$$

the weight of the gases released, ωz, follows the law of Noble & Abel, and we therefore have the formula:

$$P = f \frac{\omega z}{\left[c' - \frac{\omega}{\delta}(1-z)\right] - \eta \omega z},$$

which gives the solution sought.

Expressing this formula under the form:

$$P = f \frac{\omega z}{c' - \eta \omega} \quad \frac{1}{1 + \frac{1-z}{c' - \eta \omega}\left(\eta - \frac{1}{\delta}\right)\omega}$$

we note that the term $\frac{1-z}{c' - \eta \omega}\left(\eta - \frac{1}{\delta}\right)\omega$, of the denominator, vanishes when $\eta = \frac{1}{\delta}$, that is, when the covolume is equal to the reciprocal of the density, as happens in the case of black powders. This term is also zero when the grain is entirely consumed, for then $z = 1$.

We thus see that the simple formula:

$$P = f \frac{\omega z}{c' - \eta \omega}$$

may, in certain cases, represent very accurately the law of the developemnt of the pressures of the powder in closed vessels as a function of the fraction of powder burned, and we shall at the same time see that this simple law gives the first term of the series in the ballistic theories.

Placing:
$$b=\frac{\eta-\frac{1}{\delta}}{c'-\eta\omega}\qquad \omega=\frac{\eta-\frac{1}{\delta}}{\frac{1}{\Delta}-\eta}$$

we have:
$$P=f\frac{\omega z}{c'-\eta\omega}\;\frac{1}{1+b\,(1-z)}$$

as the generalized formula of the law of Noble & Abel.

Introducing the pressure P′, we have:

$$P=\frac{P'\,z}{1+b\;(1-z)}$$

In the experiments with closed vessels in which the density δ, cannot greatly exceed 0,3 without danger of bursting the vessel, the coefficient b is a small number and the product $b(1-z)$ is *a fortiori* very small compared to unity. Hence it follows this term will play but a secondary rôle in the theory.

The *a priori* value would be: $b=\frac{\eta-\frac{1}{\delta}}{\frac{1}{\Delta}-\eta}$, in which all terms are known.

However, this value cannot be regarded as regorously exact, for among the causes of its variation it is to be noted that an error is committed by taking for δ the density of the cold powder, since for a temperature of the order of 3000°, which is the temperature of explosion of *poudre B*, the expansion of the powder is not negligible. But these are problems involving an approximation of the 3d degree, which the present state of the science of Interior Ballistics does not permit of consideration. Hence we will take the law (P,z) which connects the pressures P to the fraction z of the powder burned during the entire time of combustion, under the form:

$$P=P'\frac{z}{1+b\;(1-z)},$$

in which

$$P'=f\frac{\omega}{c'-\omega'},=f\,\frac{\Delta}{1-\eta\Delta},$$

$$b=\frac{\eta-\frac{1}{\delta}}{\frac{1}{\Delta}-\eta},\qquad \omega'=\eta\omega.$$

Remark.—For certain theoretical questions of the development of the pressures at the origin of the times of burning, it is to be observed that for $z=0$, P is not zero, but equal to P_a, where P_a designates the atmospheric pressure. For these special cases we must therefore write:

$$P=P_a+(P'-P_a)\frac{z}{1+b\;(1-z)}.$$

We know that $P_a = 103$ Kg per square decimeter. The ratio $\frac{P_a}{P'}$ is generally, then, extremely small, of the order of 1/1000.

THEORY OF THE COMBUSTION OF POWDERS IN CLOSED VESSELS

SEC. 1.—DETERMINATION OF THE LAWS OF COMBUSTION AT CONSTANT VOLUME

III. *Influence of the Pressure.*—A ballistic powder, that is, one which possesses a *form function* φ (z), may be represented by a combustion formula:

$$\frac{dz}{dt} = A_1\,\varphi(z),$$

at constant pressure.

The hypothesis of the existence of the form function assumes that φ (z) is independent of the weight ω of the charge, of the pressure P, under which the combustion is effected and of the volume c′ of the vessel. Hence the pressure P can only be introduced in the coefficient A_1.

The velocity of combustion $\frac{dz}{dt}$ increases with the pressure. A colloidal powder does not burn in vacuo, so that if an electric current be passed through a wire in contact with the powder and brought to a red heat the flame will not be propagated but simply a furrow be hollowed in the powder grain.

Several investigators have endeavored to determine the function of P representing the variation of $\frac{dz}{dt}$ with the pressure. With French powders, the researches of M. Vieille and those of the Central Naval Laboratory, are the only ones which have dealt with pressures of the order of those encountered in firearms.

It is quite certain that the experiments, in the present state of experimental Interior Ballistics, with all the hypotheses assumed by it and the difficulties encountered, can pretend to give but a general outline of the phenomenon. We proceed in this case then, as in the study of a mass of natural phenomena, by adopting a monominal formula as an analytical representation of the unknown relation. The exponent α will then be sought in the experiment as one of the *characteristics* of powders.

A knowledge of this characteristic will serve to determine the physical laws necessary to Pyrostatics for the complete solution of the problem of the combustion of powder in closed vessels.

We will therefore write the differential equation of the combustion under the form:

$$\frac{dz}{dt} = A\varphi\,(z)\,P^{\alpha}.$$

The coefficient A is called the *quickness* of the powder and, in the symbolic geometric interpretation of the form function, is expressed by $A = \frac{S_0\delta}{Q} w$, [*] in which w is the linear velocity of combustion under unit pressure.

IV. Statement of the Pyrostatic Problem.—This problem may be stated as follows:

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[*] Translator's Note.—S_0 is the initial surface of combustion and Q the weight of the charge.

Given any powder whose characteristics (f, η, b), under the law of Nobel & Abel, have been determined from experiments in a closed vessel, how can we experimentally

(a) infer whether this powder admits a form function,
(b) determine this function,
(c) determine the exponent α, of the pressure,
(d) determine the quickness A?

The study of the forms of the curve (P,t) obtained in the vessel under different conditions of loading (Δ variable), will permit of solving this problem through the discussion of the consequences of the two laws which we have just assumed:

$$[1] \qquad P = P' \frac{z}{1+b\,(1-z)},$$

$$[2] \qquad \frac{dz}{dt} = A\varphi\,(z)\,P^{\alpha}.$$

V. Curve (z,t).—The experiment as is known, permits of tracing the curve (P,t) of pressures as a function of the time.

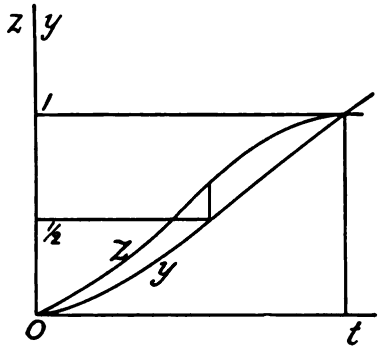

FIG. 1. 2489

The curve (z,t) (Fig. 1) can be deduced from formula [1]:

$$\frac{P}{P'} = \frac{z}{1+b\,(1-z)}.$$

However, it is to be observed that the curve (z,t) approaches very nearly the curve $(\frac{P}{P'},t)$, since, from what has been said, the term in b is only a correction term, the square of which may be neglected. Placing $y = \frac{P}{P'}$, equation [1] may be written under the form:

$$y\,[1+b\,(1-y)] = z$$

which gives a value of z for each value of y.

Differentiating, we have

$$\frac{dy}{dt}\,[1+b\,(1-2y)] = \frac{dz}{dt}$$

from which we see that the curve z is above the curve y, having two points in common with it, namely, $z=0$ and $z=1$. The difference $z-y=by\,(1-y)$

is a maximum for $y = \frac{1}{2}$ and has a value at this point of $(z-y)_{\max} = \frac{b}{4}$. The two tangents at this point of the two curves are moreover parallel.

The ratio of the tangents to the curves z and y at the origin is $(1+b)$. At the end of the combustion this ratio is $(1-b)$.

As the curves (z,t) do not depend on the absolute pressure, but on the ratio $y = \frac{P}{P'}$, we may trace the curves obtained from firing with different densities of loading on the same diagram.

The experimental diagram which we will utize will then consist of a series of curves (z,t), $OI_{1,2,3,4}$ . . . , corresponding to the different densities of loading $\Delta_{1,2,3,4}$ . . .

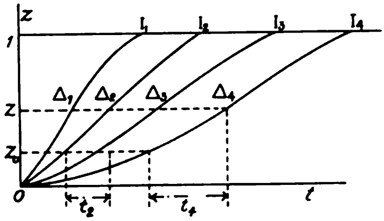

FIG. 2. 2490

This is the diagram (fig. 2) we can utilize for the verifications and determinations sought.

VI. Equation of the Curve in a Closed Vessel.—Eliminating P in equations [1] and [2], we have

$$\frac{dz}{dt} = AP'^{\alpha} \frac{z^{\alpha}\varphi(z)}{[1+b(1-z)]^{\alpha}}$$

whence we have

$$AP'^{\alpha}\, dt = [1+b\,(1-z)]^{\alpha} \frac{dz}{z^{\alpha}\,\varphi(z)},$$

By developing the binomial in the second member, we have

$$AP'^{\alpha}\, dt = [1+\alpha b\,(1-z)] \frac{dz}{z^{\alpha}\,\varphi(z)},$$

Integrating between the limits z_0 and z, in which z_0 is the lower and z the upper limit, we have

$$[3] \qquad AP'^{\alpha}\, t = \int_{z_0}^{z} \frac{dz}{z^{\alpha}\,\varphi(z)} + \alpha b \int_{z_0}^{z} \frac{(1-z)\,dz}{z^{\alpha}\,\varphi(z)}.$$

This is the fundamental formula of pyrostatics, based on the assumed hypotheses and the established experimental laws. The second term of the second member, involving as it does the coefficient b, is a secondary term, very small compared to the first.

VII. Theorem that a form function exists.—1° Let us first consider the principal term of the series:

$$AP'^{\alpha}\, t = \int_{z_0}^{z} \frac{dz}{z^{\alpha}\,\varphi\,(z)}.$$

The integral in the second member depends only on the limits z and z^0. Hence, we can state the following theorem:

In a series of curves (z,t) corresponding to densities of loading between the two limits (z, z_0), the terms satisfy the relation

$$P'^{\alpha}_1 t_1 = P'^{\alpha}_2 t_2 = P'^{\alpha}_3 t_3 = \text{constant}.$$

Hence, all the curves are capable of superposition, provided a unit is taken for the time interval inversely proportional to P'^{α}.

Thus, then, the necessary and sufficient condition for the existence of a form function is that over the whole portion of the curves (z,t) within two arbitrary limits z and z_0, $P'^{\alpha}t$ = a constant, whatever be the density of loading Δ.

If this condition is realized, the ratio of similitude of any two curves gives $\frac{t_1}{t_2} = \left(\frac{P'_2}{P'_1}\right)^{\alpha}$, whence the exponent can be determined.

By this method it may moreover be ascertained whether it be admissible to represent the influence of the pressure by a monomial affected by a constant α, because the value of α might vary from arc to arc; there would then be a means of determining the function Φ (P) which should enter the generalized formula:

$$\frac{dz}{dt} = A\,\Phi(P)\,\varphi(z).$$

2. Introducing now the second term of the series we will proceed, by an analogous method, to make this verification by considering successive arcs of the curve (z,t).

For two very small homologous arcs of the curves Δ_1 and Δ_2, we may write:

$$AP'^{\alpha}_1\ dt_1 = [1 + \alpha b_1\ (1 - \zeta)] \frac{dz}{z^{\alpha}\ \varphi(z)},$$

$$AP'^{\alpha}_2\ dt_2 = [1 + \alpha b_2\ (1 - \zeta)] \frac{dz}{z^{\alpha}\ \varphi(z)}$$

in which ζ is a mean value between z_0 and z.

Hence, we have:

$$\left(\frac{P'_1}{P'_2}\right)^{\alpha} \frac{t_1}{t_2} = 1 + \alpha\ (b_1 - b_2)\ (1 - \zeta);$$

and as the second member is known, we see that the first member fully satisfies this relation throughout the length of both curves.

3.—Considering the tangents at the same points z of the curves Δ, since we have

$$\frac{dz}{dt} = AP'^{\alpha}\ z^{\alpha}\varphi\ (z),$$

we may, as a first approximation write:

$$\frac{\left(\frac{dz}{dt}\right)_1}{\left(\frac{dz}{dt}\right)_2} = \left(\frac{P'_1}{P'_2}\right)^{\alpha}$$

whence α can be determined by measuring the tangents of the angles (Fig. 3).

4. By these or other similar methods, we may ascertain *with an approximation admissible by our researches*: 1°. that modern colloidal powders really admit a function of form; 2° that the exponent α of the pressure may be taken equal to unity.

The latter hypothesis, unless explicitly excepted, will be assumed in all the calculations.

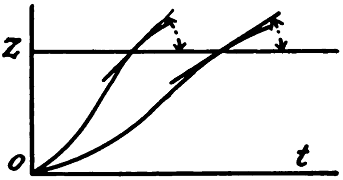

FIG. 3. 2491

VIII. DETERMINATION OF THE FORM FUNCTION. Let us now consider one of the curves (z,t) obtained, say, by the superposition according to the law of similitude, of all the other curves (Fig. 4)

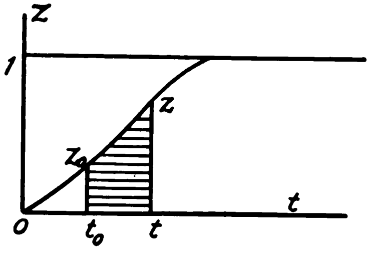

FIG. 4. 2492

Its differential equation will be:

$$\frac{dz}{dt} = A\,\varphi\,(z)\,\frac{z}{1+b(1-z)},$$

which may be written:

$$[1] \qquad \int_{t_0}^{t} z\,dt = \frac{1}{A}\int_{z_0}^{z}[1+b\,(1-z)]\frac{dz}{\varphi\,(z)}$$

Now the first member represents the area $(z_0 t_0, zt)$; the second member, assuming a small element of the curve, may be written:

$$\int_{t_0}^{t} z\,dt = \frac{1+b\,(1-\zeta)}{A}\int_{z_0}^{z}\frac{dz}{\varphi(z)}.$$

in which ζ is taken as an approximate mean between z_0 and z.

Placing the integral

$$\int_{z_0}^{z}\frac{dz}{\varphi(z)} = M(z)$$

the above expression becomes:

$$\int_{t_0}^{t} z\,dt = \frac{1+b\,(1-\zeta)}{A}\,[M(z) - M(z_0)],$$

or more simply:

$$[2] \qquad \int_{t_0}^{t} z\,dt = \frac{1+b\,(1-\zeta)}{A}\,(M-M_0).$$

Now, since the term $[1+b(1-\zeta)]$ is known at each instant, by evaluating the area (z,t) for successive arcs, a numerical table can be constructed of the integral $M(z)$, called the *ballistic function* of *powders.*

Now, this function $M(z)$ is that which is introduced in all the theories of Interior Ballistics, rather than the function $\varphi(z)$, which, moreover, can be deduced from the table of the function M, since by definition, we have

$$\frac{dM}{dz}=\frac{1}{\varphi(z)}.$$

Thus we obtain the following fundamental result:

The ballistic function $M(z)=\int_{0}^{z}\frac{dz}{\varphi(z)}$, which depends on the form function φ (z) and may serve, under the same title, to characterize the mode of combustion of a powder, can be obtained experimentally.

Remark. If owing to the approximation made in the choice of ζ it is thought the function M (z) has not been determined with sufficient precision by formula [2], we can proceed to determine it by a double approximation by writing:

$$\int_{t_0}^{t} z\,dt = \frac{1}{A}\,(1+b)(M-M_0)-\frac{b}{A}\int_{z_0}^{z} z\,dM,$$

and computing the function $z\,dM$ by the first approximation.

IX. Remarks on the curve (z,t). 1°. Tangent.—The differential equation of the fundamental curve (z,t) is:

$$\frac{dz}{dt}=AP'\,\varphi\,(z)\,\frac{z}{1+b(1-z)}.$$

At the origin, where $z=0$, the expression for the tangent takes the form:

$$\left(\frac{dz}{dt}\right)_0=\frac{AP'\,\varphi\,(o)}{1+b}\times o.$$

Hence, unless φ (o) be infinite, which can only correspond to a limiting case for an extremely small grain powder having an analytically zero time of burning, we will have:

$$\left(\frac{dz}{dt}\right)_0=0.$$

When the powder has been consumed, that is, when $z=1$, we have:

$$\left(\frac{dz}{dt}\right)_1=AP'\,\varphi\,(1).$$

Hence the tangent at the point $(z=1)$ does not depend on the secondary term in b. The tangent is horizontal when $\varphi(1)=0$, otherwise it is inclined.

2. Point of Inflection.—Let us see if there is a point of inflection on the curve (z,t). We have:

$$\frac{d^2z}{dt^2}=AP'\left[(z\varphi'+\varphi)\;[1-b(1-z)]+bz\varphi\right]\frac{dz}{dt}.$$

There will be a point of inflection if we have:

$$z\varphi' + \varphi = \frac{-bz\varphi}{1 - b\,(1 - z)},$$

or, with the approximation assumed,

$$\frac{\varphi'}{\varphi} + \frac{1}{z} = -b.$$

This relation (as a first approximation: $\frac{\varphi'}{\varphi} + \frac{1}{z} = 0$) determines the value z_i of the fraction burned at the point of inflection. We see that a point of inflection can only exist if φ' is of contrary sign to φ; that is, when the function φ deceases as z increases. The degressive powders* are the only ones which may admit a point of inflection for the curve (z,t).

3. Integral.—For $\alpha = 1$, equation [3] becomes:

$$AP't = \int_{z_0}^{z} \frac{dz}{z\varphi(z)} + b \int_{z_0}^{z} \frac{(1 - z)\,dz}{z\varphi(z)}.$$

Introducing a new *ballistic function* of *powders*, or

$$L(z) = \int_{0}^{z} \frac{dz}{z\varphi(z)},$$

and designating it by the abbreviation L, we have:

$$AP'\,t = L - L_0 + b\,[L - L_0 - M + M_0]$$

Given the function M, we can readily construct a table of the function:

$$L\,(z) = \int_{0}^{z} \frac{dM}{z}.$$

The problem of the combustion of the powder in closed vessels is thus completely solved by the above equation. The principal term is:

$$AP'\,t = L - L_0.$$

A secondary term has the coefficient b as a factor and is expressed by: $b[(L - M) - (L_0 - M_0)]$, a function for which a single double entry table can be constructed.

Remarks.—*1.* The formula which gives AP't is eaxct, *whatever the value of b.* In case $\alpha = 1$. the integration does not require the development into a series.

2. In the operations indicated above we see that the functions M and L have been determined only as a factor of A, and that these formulas alone do not permit of obtaining the absolute value of the *quickness* A. The latter is therefore but a relative quantity and we must choose some value for it as a unit for constructing the tables.

If, on the contrary, we choose a priori or by analogy, the function $\varphi(z)$ under an abstract form, for example $\varphi(z) = (1 - z)^{\beta}$ that is, by imposing a value 1 for $z = 0$, for example, we can, a priori, construct the tables of the functions M and L and deduce the *quickness*, which may be designated as *absolute*, from the formula:

$$AP'\,t = L - L_0 + b\,[L - M - (L_0 - M_0)].$$

(*) Translator's note. — By a degressive powder is meant one which presents a decreasing burning surface during conbustion.

4. Asymptotes. — From the formula which gives the integral of the time under the form:

$$AP't = L - L_0 + b\,[(L - M) - (L_0 - M_0)].$$

in which $L\,(z) = \int_0^z \frac{dz}{z\varphi\,(z)}$, there will be an asymptote at the origin, the axis of t, if when $\varphi(o) = o$, the integral $\int_0^z \frac{dz}{z\varphi\,(z)}$ has an infinite value.

There will be an asymptote when the powder is completely burned ($z = 1$), if when $\varphi(1) = o$, the integral $\int_1^z \frac{dz}{z\varphi\,(z)}$ has an infinite value.

5. Origin of the curve (z,t). — We have seen that for $z = o$, we have $t = \infty$. This result comes from having neglected in the general equations the atmospheric pressure P_a, for which we have in reality $z = o$.

This hypothesis is always admissible in the practical applications of Pyrostatics, where P′ is infinitely large in comparison with the atmospheric pressure.

From an analytical point alone it is useless to make the calculations below for deducing the form of the curve (z,t). To study the curve (z,t) in the neighborhood of the origin, it is necessary to place the equations under the form:

$$\frac{dz}{dt} = A\varphi\,(z)\,P, \qquad P = P_a + \frac{P' - P_a}{1 + b(1 - z)}\,z.$$

Placing $y = \frac{P}{P'}$, and $y_0 = \frac{P_a}{P'}$, the latter becomes

$$y = y_0 + (1 - y_0)\frac{z}{1 + b(1 - z)}\,.$$

We then have:

$$\frac{dz}{dt} = AP'\left[y_0 + (1 - y_0)\frac{z}{1 + b(1 - z)}\right]\varphi\,(z)$$

Let φ (z), in the neighborhood of the origin, be developed into a series:*

$$\varphi(z) = \varphi(o) + z\,\varphi'(o) + \ .\ .\ .$$

we will have:

$$\frac{dz}{dt} = AP'\varphi\,(o)\left[y_0 + (1 - y_0)\,\frac{z}{1 + b}\right]\left[1 + \frac{\varphi'(o)}{\varphi\,(o)}\,z\right].$$

Hence:

$$[1]\qquad \frac{dz}{dt} = AP'\,\varphi(o)\left[y_0 + \left(y_0\frac{\varphi'(o)}{\varphi\,(o)} + \frac{1 - y_0}{(1 + b)}\right)z\;\right].$$

Making $z = o$, we have for the tangent at the origin of the curve (z,t):

$$\frac{dz}{dt} = AP_a\,\varphi(o),$$

which is independent of the coefficient b.

Depending upon the value of φ (z) for $z = o$, the tangent will have an oblique, a vertical or horizontal direction. All the curves (z,t) thus admit of but one and the same tangent at the origin (fig. 5).

---

* By MacLaurin's Theorem (Trans.)

The integration of equation [1] above, readily gives:

$$AP_a\varphi(o)\left[\frac{\varphi'(o)}{\varphi\,(o)}+\frac{1-y_0}{y_0\,(1+b)}\right]t=\log\left[1+\left(\frac{\varphi'(o)}{\varphi\,(o)}+\frac{1-y_0}{y_0\,(1+b)}\right)z\right].$$

which for $z=o$ gives $t=o$.

The fraction of the powder which must be burned to give space for the pressure P_a will be:

$$z_0=-\frac{1}{\dfrac{\varphi'(o)}{\varphi\,(o)}+\dfrac{1-y_0}{y_0(1+b)}}.$$

X. Example of a degressive type of powder. As from a practical point of view, the *form function*

$$\varphi(z)=(1-z)^{\beta}$$

permits of ballistically defining quite a number of modern colloidal powders by means of a single characteristic β, we will here make rather a detailed study of their curve (z,t) in a closed vessel.

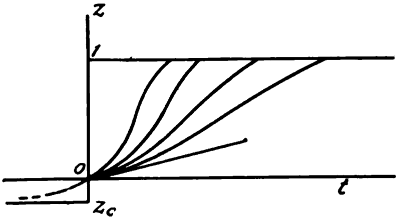

FIG. 5. 2493

1°.— First we will take the general formula with the exponent α of the pressures, in order to show how this exponent may be determined in the actual case outside the general method.

The formula:

$$\frac{dz}{dt}=AP'^{\alpha}\,\frac{z^{\alpha}\,\varphi\,(z)}{[1+b(1-z)]^{\alpha}},$$

will here be written:

$$\frac{dz}{dt}=AP'^{\alpha}\,[1-\alpha b\,(1-z)]\;z^{\alpha}\;(1-z)^{\beta}.$$

Since, when $\alpha>o$ and $\beta>o$, the two tangents at the origin and at the point $z=1$, are horizontal, a poiut of inflection z_i exists on the curve (x,t). We have:

$$\frac{d^2z}{dt^2}=\left[\frac{\alpha}{z}-\frac{\beta}{1-z}+\frac{b\,\alpha}{1-\alpha b(1-z)}\right]\left(\frac{dz}{dt}\right)^2$$

The point of inflection z_i, therefore corresponds to the equation

$$\frac{\alpha}{z_i}-\frac{\beta}{1-z_i}+b\alpha=o.$$

This is the analog, in the actual case, of the formula

$$\frac{\varphi'}{\varphi}+\frac{1}{z}=-b.$$

As, in the first approximation, we have $z_i=\frac{\alpha}{\alpha+\beta}$, we will have for the expression of z_i:

$$z_i=\frac{\alpha}{\alpha+\beta}\left[1+b\frac{\alpha\,\beta}{(\alpha+\beta)^2}\right].$$

substituting the first value for z_i in the expression for $\frac{dz}{dt}$, we obtain the formula:

$$\left(\frac{dz}{dt}\right)_i=AP'^{\alpha}\left(1-b\frac{\alpha\beta}{\alpha+\beta}\right)\frac{\alpha^{\alpha}\,\beta^{\beta}}{(\alpha+\beta)^{\alpha+\beta}},$$

which defines the tangent at the point of inflection. Thus then, all points of inflection of the different curves (z,t) are sensibly (to within the term in b nearly) on the horizontal right line $z_i=\frac{\alpha}{\alpha+\beta}$ (fig. 6).

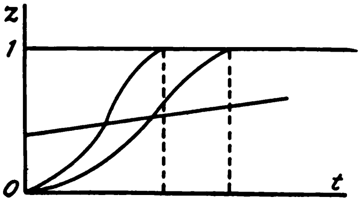

FIG. 6.

In order to determine α we will compare the values of the tangent at the points of inflection for several curves and we will have:

$$\frac{\left(\frac{dz}{dt}\right)}{P'^{\alpha}\left(1-b\,\frac{\alpha\,\beta}{\alpha+\beta}\right)}=\text{constant}.$$

which permits of determining the exponent α by a method analogous to that of par. VII.

Let us assume that we still have $\alpha=1$ and let it be required to determine the *characteristic* β of a given powder. From the equation which gives z_i as a function of β:

$$z_i=\frac{1}{1+\beta}\left(1+\frac{b\beta}{(1+\beta)^2}\right).$$

we deduce by two approximations:

$$\beta=\frac{1-z_i}{z_i}(1+bz_i).$$

2°. Functions M and L. — We have:

$$M = \int_0^z \frac{dz}{\varphi z} = \int_0^z \frac{dz}{(1-z)^\beta} = \frac{1}{1-\beta}\left[1-(1-z)^{1-\beta}\right]$$

For $z = o$, $M = o$; for $z = 1$, $M_1 = \frac{1}{1-\beta}$, if $\beta < 1$, and $M_1 = \infty$, if $\beta = 1$.

We have:

$$\frac{dM}{dz} = \frac{1}{(1-z)^\beta},$$

whence:

$$\left(\frac{dM}{dz}\right)_0 = 1, \quad \left(\frac{dM}{dz}\right)_1 = \infty.$$

The function

$$L = \int_0^z \frac{dz}{z\varphi(z)} = \int_0^z \frac{dz}{z(1-z)^\beta},$$ may be integrated by placing:

$$z = \sin^2\psi, \text{ whence } dz = 2 \sin\psi \cos\psi \; d\psi.$$

Hence $L = 2 \int_0^\psi \frac{\cos^{1-2\beta}\psi}{\sin\psi} \, d\psi$, which is an integral of a type known in analysis, but which can only be expressed as an elementary function when $(1-2\beta)$ is a whole number.

If $\beta > o$, we have $L > \int_0^z \frac{dz}{z}$, that is, $L > \operatorname{Log} z$. Hence for $z = o$, we have $L = \infty$.

Let z be very close to unity, by placing $z = 1 - \epsilon$, we have:

$$L - L_0 = \int_1^{1-\epsilon} \frac{dz}{z(1-z)^\beta} = -\int_1^{1-\epsilon} \frac{d\epsilon}{(1-\epsilon)\epsilon^\beta} = -\int_1^{1-\epsilon} \frac{d\epsilon}{\epsilon^\beta}$$

$$-\int_1^{1-\epsilon} \frac{d\epsilon}{\epsilon^{\beta-1}} = \frac{1}{\beta-1}\left[\frac{1}{\epsilon^{\beta-1}}\right]_1^{1-\epsilon} + \frac{1}{\beta-2}\left[\frac{1}{\epsilon^{\beta-2}}\right]_1^{1-\epsilon}.$$

That is, the limit $(L - L_0)$ for $z = 1$, is equal to zero if $\beta < 1$.

3°. Remark upon the origin of the curve (z,t). — If we keep the exponent α under its general form in the first term of the integral:

$$[3] \qquad AP'^\alpha \, t = \int_{z_0}^z \frac{dz}{z^\alpha \varphi(z)},$$

which here becomes:

$$AP'^\alpha \, t = \int_{z_0}^z \frac{dz}{z^\alpha (1-z)^\beta},$$

we see that for $z_0 = o$, $t = \infty$ only when $\alpha > 1$. The experimental value which we have found, $\alpha = 1$, accords well with the established fact that the powder does not burn in vacuo; an infinite time is necessary to pass from a zero pressure to that of the atmosphere, P_a.

4°. Upon combustion at a constant pressure. — If we assume that the combustion takes place in open air, it is the function M rather than the function L which permits the determination of the time of burning.

We have then:

$$\frac{dz}{dt} = A\varphi(z),$$

whence

$$At = \int_0^z \frac{dz}{\varphi(z)} = M - M_0,$$

and in the present case

$$At = \frac{1}{1-\beta}\left[1-(1-z)^{1-\beta}\right]$$

The total time of burning is

$$AT_1 = \frac{1}{1-\beta}.$$

It is to be observed that this formula governs phenomena like the fusion of a block of ice, the dissolution of a solid in an undefined liquid, etc.

SEC. 2.—THE PRESSURE CURVE IN CLOSED VESSELS

XI. General Formulae. In the preceding section we have studied the curve (z,t) which it was convenient to substitute for the curve (P,t) directly obtained, since it was a question of determining the laws and characteristics of the burning of powders. In the present section we will study the curve (P,t) itself.

We have obtained the equation of the curve (z,t), which connects the fraction burned to the time under the form:

$$AP't = \int_{z_0}^{z} \frac{dz}{z\varphi(z)} + b\int_{z_0}^{z} \frac{(1-z)\,dz}{z\varphi(z)}.$$

To replace z in this formula by the pressure P, we resume the formula

$$y[1+b(1-y)] = z$$

whence

$$dz = [1+b(1-2y)]\,dy$$

and

$$\varphi(z) = \varphi[y+by(1-y)] = \varphi(y) + by(1-y)\varphi'(y) + \dots$$

Hence we will have:

$$AP't = \int_{y_0}^{y} \frac{1+b(1-2y)}{[1+b(1-y)]\left[1+by(1-y)\frac{\varphi'}{\varphi}\right]}\frac{dy}{y\varphi(y)} + b\int_{y_0}^{y} \frac{1-y}{y\varphi(y)}dy,$$

or:

$$AP't = \int_{y_0}^{y} \frac{dy}{y\varphi(y)} + b\int_{y_0}^{y}\left[1-2y-y(1-y)\frac{\varphi'}{\varphi}\right]\frac{dy}{y\varphi(y)},$$

or again:

$$AP't = L(y) - L(y_0) + b\left(L - L_0 - 2(M - M_0) - \operatorname{Log}\frac{\varphi}{\varphi_0} + y\operatorname{Log}\varphi - y_0\operatorname{Log}\varphi_0 - \int_{y_0}^{y}\operatorname{Log}\varphi\,dy\right),$$

or finally:

$$AP't = L(y) - L(y_0) + b\,[P(y) - P(y_0)].$$

The parenthesis may, in fact, be reduced to a single function of y and y_0.

This formula is rather complicated and becomes still more so when we attempt to complete it for the study of the combustion in the vicinity of the origin. In fact, neglecting the term in b, we have:

$$\frac{dy}{dt} = AP'\,[y_0 + (1-y_0)y]\varphi(y),$$

whence:

$$AP't = \int_{z_0}^{z} \frac{dy}{[y_0+(1-y_0)y]\varphi(y)}.$$

Now in the vicinity of the origin we may assume the term y_0, small relatively to the term $(1-y_0)y$, which approaches zero and consequently this function is not integrable unless φ (y) is an explicit function.

Hence in the discussion which follows we will take simple cases in which the integration can be completely effected in the detailed study of the curve (P,t).

XII. Curve (P,t) of degressive powders of the type $(1-z)^\beta$.

1°. General Case. Let us take the two equations expressed in the complete form (that is, including the terms in b and P_a):

$$\frac{dz}{dt} = A(1-z)^\beta P, \qquad P = P_a + \frac{P'-P_a}{1+b\,(1-z)}\,z.$$

Placing $y = \frac{P}{P'}$, and $y_0 = \frac{P_a}{P'}$, the second equation may be written:

$$y = y_0 + \frac{1-y_0}{1+b\,(1-z)}\,z,$$

whence we deduce:

$$z = \frac{y-y_0}{1-y_0}\left(1 + b\frac{1-y}{1-y_0}\right),$$

$$1 - z = \frac{1-y}{1-y_0}\left(1 - b\frac{y-y_0}{1-y_0}\right),$$

$$dz = \frac{1}{1-y_0}\left(1 + \frac{b}{1-y_0}\,(1+y_0-2y)\right)dy.$$

The first equation then becomes:

$$\frac{1}{1-y_0}\left[1 + \frac{b}{1-y_0}\left\{1-2y+y_0\right\}\right]\frac{dy}{dt} = AP'y\,\left(\frac{1-y}{1-y_0}\right)^\beta\left[1 - b\,\beta\left(\frac{y-y_0}{1-y_0}\right)\right]$$

whence:

$$\frac{dy}{dt} = AP'(1-y_0)^{1-\beta}\,(1-y)^\beta y\,\left(1 - \frac{b}{1-y_0}\left\{\,1+y_0\,(1-\beta)+y\,(\beta-2)\,\right\}\right).$$

Integrating, we have:

$$[1] \qquad AP'(1-y_0)^{1-\beta}\,t = \int_{y_0}^{y}\frac{dy}{y\,(1-y)^\beta} -$$

$$\frac{b}{1-y_0}\left\{1+y_0\,(1-\beta)\right\}\int_{y_0}^{y}\frac{dy}{y(1-y)^\beta} - \frac{b(\beta-2)}{1-y_0}\int_{y_0}^{y}\frac{dy}{(1-y)^\beta}$$

This is the general equation of the curve (P,t).

For $t=o$, the curve starts from the point $y_0 = \frac{P_a}{P'}$ with a tangent:

$$\left(\frac{dy}{dt}\right)_0 = AP'y_0(1-y_0)(1-b),$$

or:

$$\left(\frac{dP}{dt}\right)_0 = AP'P_a(1-y_0)(1-b).$$

This tangent is directed at first in the direction of the axis of t, when $y_0=1$ $(P'=P_a)$; when the maximum pressure P' is considerable (y_0 negligible in comparison with unity), $\left(\frac{dP}{dt}\right)_0 = AP'P_a\,(1-b)$. The curve presents a point of inflection $(P,t)_i$ defined by the equation:

$$o = \frac{1}{y_i} - \frac{\beta}{1-y_i} - \frac{(\beta-2)b}{[1-b\{1+y_0(1-\beta)+y_i(\beta-2)\}](1-y_0)},$$

or:

$$\frac{P_i}{P'} = \frac{1}{1+\beta}\left[\;1-\frac{b}{(1-y_0)}\,\frac{\beta(\beta-2)}{(1+\beta^2)}\right]$$

At the *point of inflection, we have:*

$$\left(\frac{dP}{dt}\right)_i = AP'^2(1-y_0)^{1-\beta}\frac{\beta^\beta}{(1+\beta)^{\beta+}}\left[1-\frac{b}{1-y_0}\left(1+y_0(1-\beta)+\frac{\beta-2}{1+\beta}\right)\right].$$

We observe that the two points of inflection on the two curves (z,t) and (P,t), both for $y=o$, do not correspond to the two homologous points of the two curves connected by the relation $y = \frac{z}{1+b(1-z)}$, at least in that which concerns the correction term in b.

The curve terminates at the point (P',T_1) corresponding to $z=1$ and the total time of burning is:

$$\text{(2)}\qquad AP'(1-y_0)^{1-\beta}T_1 = \int_{y_0}^{1}\frac{dy}{y(1-y)^\beta} -$$

$$\frac{b}{1-y_0}\left\{1+y_0(1-\beta)\right\}\int_{y_0}^{1}\frac{dy}{y(1-y)^\beta} - \frac{b(\beta-2)}{1-y_0}\int_{y_0}^{1}\frac{dy}{(1-y)^\beta}.$$

If $\beta<1$, the point $(P'T_1)$ is at a finite distance.
If $\beta>1$, the point $(P'T_1)$ is at infinity.

For $z=1$, we have $\left(\frac{dP}{dt}\right)_1 = o$, unless $\beta=o$. The tangent is generally then horizontal.

When P' is large with respect to P_a , we may neglect y_0 as compared to unity, and we have:

$$\text{(3)}\quad AP'T_1 = \int_{y_0}^{1}\frac{dy}{y(1-y)^\beta} - b\int_{y_0}^{1}\frac{dy}{y(1-y)^\beta} - b(\beta-2)\int_{y_0}^{1}\frac{dy}{(1-y)^\beta}.$$

Equation [2] represents the locus of the points in which the combustion of the powder ends when the density of loading is varied; it is the curve of P' as a function of T_1.

When P' approaches P_a, $(1-y_0)$ approaches zero. Hence we see that T_1 approaches infinity. It approaches zero when P' approaches infinity.

The curves (P',t) when $\beta < 1$ presents itself under the aspect shown in figure 7.

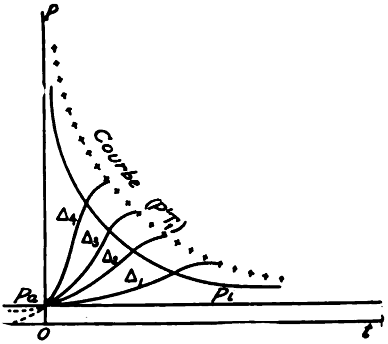

Fig. 7.

For $\beta \geq 1$, there is no curve (P',T_1); the curves (P,t) are asymptotes to the horizontals P' (fig. 7).

2°. Constant burning powders, $\beta = 0$.—The constant burning powders defined by $\beta = 0$, or, generally, by the condition $\varphi(z) = 1$, are those which have a constant velocity of emission at a constant pressure.

For their differential equation, we have:

$$\frac{dy}{dt} = AP'(1-y_0)y\left[1 - \frac{b}{1-y_0}\left\{1 + y_0 - 2y\right\}\right],$$

whence, by integrating, we have:

$$AP'(1-y_0)\,t = \operatorname{Log}\frac{y}{y_0} - \frac{b}{1-y_0}\left[(1+y_0)\operatorname{Log}\frac{y}{y_0} - 2(y-y_0)\right].$$

Introducing the pressure P and substituting $\frac{P}{P'}$ for y, it becomes:

$$\frac{dP}{dt} = AP(P'-P_a)\left[1 - \frac{b}{P'-P_a}(P'+P_a-2P)\right]$$

and,

$$A(P'-P_a)\,t = \operatorname{Log}\frac{P}{P_a} - \frac{b}{P'-P_a}\left[(P'+P_a)\operatorname{Log}\frac{P}{P_a} - 2(P-P_a)\right].$$

At the origin the tangent is expressed by:

$$\left(\frac{dP}{dt}\right)_0 = AP_a(P'-P_a)\,(1-b).$$

At the end of the combustion, when $z=1$, which is also a point of inflection, we have:

$$\left(\frac{dP}{dt}\right)_1 = AP'(P'-P_a)\,(1+b).$$

The total time of burning is given by the formula:

$$A(P'-P_a)T_1 = \left(1-b\,\frac{P'+P_a}{P'-P_a}\right)\text{Log}\,\frac{P'}{P_a} + 2b.$$

For large values of P'(P_a negligible compared to P') and neglecting the terms in b, we obtain:

$$AP't = \text{Log}\,\frac{P}{P_a},$$

whence

$$P = P_a e^{AP't}.$$

The curve (P', T_1) is then close to the curve:

$$AP'T_1 = \text{Log}\,P' - \text{Log}\,P_a \text{ (Fig. 8).}$$

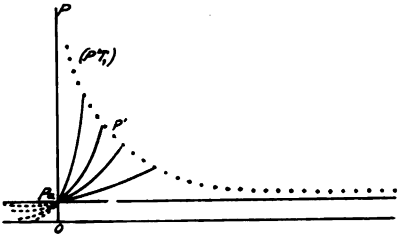

FIG. 8.

3. Cylindrical powders (cordite $\beta = \frac{1}{2}$).—Let us neglect the term b in this discussion.

We will have:

$$AP'(1-y_0)^{1/2}t = \int_{y_0}^{y} \frac{dy}{y(1-y)^{1/2}}.$$

To integrate, place $1-y = \sin^2\varphi$, whence $y = \cos^2\varphi$ and

$$dy = -2\sin\varphi\cos\varphi.$$

Then:

$$\int_{y_0}^{y} \frac{dy}{y(1-y)^{1/2}} = -2\int_{\varphi_0}^{\varphi} \frac{d\varphi}{\cos\varphi}.$$

But:

$$\int_0^{\varphi} \frac{d\varphi}{\cos\varphi} = \text{Log}\tan\left(\frac{\pi}{4}+\frac{\varphi}{2}\right) = \log\frac{1+\tan\frac{\varphi}{2}}{1-\tan\frac{\varphi}{2}}$$

We will then have by a known transformation:

$$\int_{y_0}^{y}\frac{dv}{y(1-y)^{1/2}} = \text{Log}\,\frac{1+\sin\varphi_0}{1-\sin\varphi_0}\,\frac{1-\sin\varphi}{1+\sin\varphi}.$$

We thus have:

$$AP'(1-y_0)^{1/2}\,t = \text{Log}\,\frac{1+\sin\varphi_0}{1-\sin\varphi_0}\,\frac{1-\sin\varphi}{1+\sin\varphi},$$

in which $y = \cos^2\varphi$.

At the point $z = 1$, we have $\varphi = o$. Hence:

$$AP'(1-y_0)^{1/2}T_1 = \text{Log}\,\frac{1+\sin\varphi_0}{1-\sin\varphi},$$

and if y_0 is small compared to unity, $\sin\varphi_0 = 1 - \frac{1}{2}y_0$, and we have

$$AP'T_1 = \text{Log}\,\frac{4P'}{P_a}.$$

There is a point of inflection corresponding to

$$y_i = \frac{1}{\beta+1} = \frac{2}{3}. \qquad \text{Hence } \sin\varphi_i = \frac{1}{\sqrt{3}}.$$

Hence we will have (y_0 being small compared to unity):

$$AP't_i = \text{Log}\,\frac{4P'}{P_a}\,\frac{1-\sin\varphi_i}{1+\sin\varphi_i}$$

$$= \text{Log}\,\frac{4P'}{P_a}\,\frac{\sqrt{3}-1}{\sqrt{3}+1} = \text{Log}\ 1.17\,\frac{P'}{P_a}.$$

The tangent at the point of inflection is determined by the relation:

$$\left(\frac{dP}{dt}\right)_i = AP'^2\,\frac{\beta^\beta}{(1+\beta)^{\beta+1}} = AP'^2\,\frac{2}{3\sqrt{3}}.$$

4°. Case of $\beta = 1$.—If the term in b is assumed negligible, we have

$$AP't = \int_{y_0}^{y}\frac{dy}{y(1-y)};$$

that is,

$$AP't = \text{Log}\,\frac{P}{P_a}\,\frac{P'-P_a}{P'-P}.$$

For the tangent at any point, we have:

$$\frac{dP}{dt} = A(P'-P_a)P:$$

and at the origin:

$$\left(\frac{dP}{dt}\right)_0 = AP_a(P'-P_a).$$

The point of inflection occurs at a point P_i, such that $P_i = \frac{1}{2} P'$.

At this point, $\left(\frac{dP}{dt}\right)_i = A \frac{P'^2}{4}$.

The time of burning to this point is:

$$AP't_i = \text{Log}\,\frac{P'-P_a}{P_a}.$$

The total time of burning T_1 is infinite.

5°. Figure 9 summarizes the properties of the combustion curves of degressive powders of the type $\varphi(z) = (1-z)^\beta$.

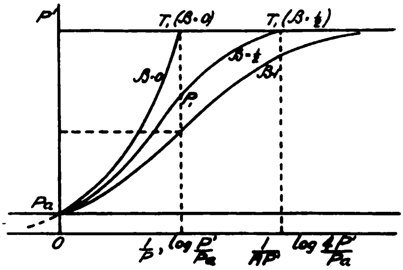

FIG. 9.

XIII. Powders of the type: $\varphi(z) = 1 + hz$.—1° Progressive powders. Let $\varphi(z) = 1 + hz$, be the form function of a progressive powder; we will have for its equation (neglecting the term in b):

$$\frac{dz}{dt} = A(1+hz)P;\ P = P_a + (P'-P_a)z.$$

Hence we will have:

$$\frac{dP}{dt} = A(P'-P_a)\left[1+h\,\frac{P-P_a}{P'-P_a}\right]P;$$

or, placing $\frac{P}{P'} = y$:

$$\frac{dy}{dt} = AP'(1-y_0)\left[1+h\frac{y-y_0}{1-y_0}\right]y;$$

hence:

$$AP't = \int \frac{dy}{y\,[1-(h+1)y_0+hy]}.$$

Placing $h_1 = 1-(h+1)y_0$ we have:

$$AP't = \frac{1}{h_1}\int\frac{dy}{y(1+\frac{h}{h_1}y)} = -\frac{1}{h_1}\left[\frac{h}{h_1}\int\frac{dy}{1+\frac{h}{h_1}y} - \int\frac{dy}{y}\right];$$

whence:

$$AP't = -\frac{1}{h_1}\left[\text{Log}\left(1+\frac{h}{h_1}y\right) - \log y + \text{const.}\right]$$

or:

$$AP't = \frac{1}{h_1} \text{Log} \frac{y}{y_0} \frac{h_1 + hy_0}{h_1 + hy}.$$

The curve starts at the origin with a tangent:

$$\left(\frac{dP}{dt}\right)_0 = A(P' - P_a) P_a,$$

or:

$$\left(\frac{dP}{dt}\right)_0 = AP'P_a, \text{ very nearly.}$$

It terminates at the point (T_1, P') such that:

$$AP'T_1 = \frac{1}{h_1} \text{Log} \frac{P'}{P_a} \frac{h_1 P' + hP_a}{(h_1 + h)P'};$$

or:

$$AP'T_1 = \frac{1}{h_1} \text{Log} \frac{P'}{P_a} \frac{h_1}{h_1 + h} = \frac{1}{h_1} \text{Log} \frac{P'}{P_a} \frac{1 - (h+1)y_0}{(h+1)(1 - y_0)};$$

or finally;

$$AP'T_1 = \text{Log} \frac{1}{h+1} \frac{P'}{P_a} \text{ very nearly.}$$

At this point the tangent is expressed by:

$$\left(\frac{dP}{dt}\right)_1 = A(1 + h)P'^2.$$

2. Degressive powders.—If we change h to $(-h)$ we have a type of degressive powder corresponding to the case in which a thin blade is considered as burning by successive layers.

Let us seek in what case such a powder admits a *point of inflection*. We have:

$$\frac{dP}{dt} = AP'\left(1 - \frac{P}{P'}\right)P,$$

whence:

$$\frac{d^2P}{dt^2} = AP'(P' - 2hP) \frac{dP}{dt}$$

Hence:

$$P_i = \frac{P'}{2h}.$$

In order that P_i may be real, we must have $P_i < P'$, that is, $2h > 1$.

If we consider the geometric from of the small piece, we have:

$$h = 2\frac{m(l+n)}{nl}.$$

Hence:

$$4\,\frac{m(l+n)}{nl} > 1,$$

or:

$$m > \frac{nl}{4(l+n)}.$$

It is the thickness limit m, which permits a point of inflection.

Let $n = \frac{l}{4}$, we have $m > \frac{l}{20}$.

Thus for a strip 100 mm. long, we have $m > 5$ mm.

The tangent at the point P′ would be horizontal, it $h = 1$ ($m = 10$ mm. in the above example), which makes the powder coincide with that which corresponds to $\beta = 1$ in the type $(1-z)^{\beta}$.

3°.—The curves of Fig. 10 represent types of powder whose form function is $\varphi(z) = 1+hz$, separated into two divisions, one of degressive powders when $h < o$ and the other of progressive powders when $h > o$. The limit is the curve $h = o$ of the preceding paragraph.

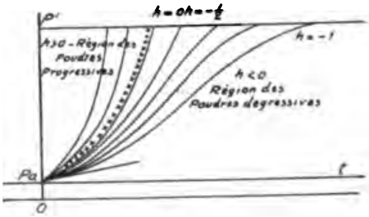

FIG. 10. 2498

4°.—The ballistic functions of powders of the type:

$$\varphi(z) = 1+hz,$$

are:

$$M(z) = \int_0^z \frac{dz}{\varphi(z)} = \frac{1}{h}\,\mathrm{Log}\,(1+hz),$$

$$L(z) = \int_0^z \frac{dz}{z\varphi(z)} = \mathrm{Log}\,\frac{z}{1+hz}.$$

XIV. Powders of the type $\varphi(z) = \frac{1}{1+h'z}$.—We will study in the same way the powders whose form function is:

$$\varphi(z) = \frac{1}{1+h'z}$$

with h′ positive for degressive powders and negative for progressive powders.

1°.—We have:

$$\frac{dP}{dt} = A(P-P_a)\frac{P}{1+h'\dfrac{P-P_a}{P'-P_a}}$$

Placing $y = \frac{P}{P'}$ and integrating, we get:

$$AP't = \frac{1}{(1-y)^2}\left[h'_1 \operatorname{Log}\frac{y}{y_0} + h'(y-y_0)\right],$$

in which $h'_1 = 1 - y_0(1+h')$.

The curve starts at the point P_a with a tangent:

$$\left(\frac{dP}{dt}\right)_0 = A(P'-P_a)P_a,$$

or.

$$\left(\frac{dP}{dt}\right)_0 = AP'P_a, \text{ very nearly.}$$

It terminates at the point $(T_1\ P')$, such that we have approximately:

$$AP'T_1 = \operatorname{Log}\frac{P'}{P_a} + h'.$$

For the tangent at this point, we have:

$$\left(\frac{dP}{dt}\right) = \frac{AP'^2}{1+h'}.$$

We have:

$$\frac{d^2P}{dt^2} = \frac{AP}{\left(1+h'\dfrac{P}{P'}\right)^2}\frac{dP}{dt}$$

and therefore there is no point of inflection on the curve (P, t) even for degressive powders.

2°.—All powders of this type are represented by the **curves** of **Fig. 11.**

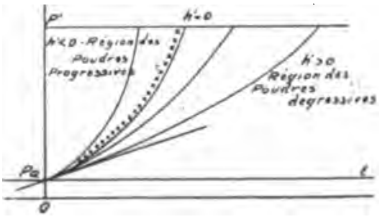
P′
h′=0
h′<0 - Région des Poudres Progressives
h′>0 Région des Poudres degressives
Pa
t
O

FIG. 11.

2490

3°.—For the ballistic functions of powders of the type:

$$\varphi(z) = \frac{1}{1+h'z},$$

we have the formulas:

$$M(z) = \int_0^z \frac{dz}{\varphi(z)} = z + \frac{h'}{2}z^2,$$

$$L(z) = \int_\varepsilon^z \frac{dz}{z\varphi(z)} = \operatorname{Log} z + h'z.$$

P. CHARBONNIER,
Engineer General of Naval Artillery.

Rivista di Artiglieria e Genio
Vol. IV. Oct.-Nov., 1918.

◆ ◆ ◆

Place of Organization of Divisions and Sources by States

Regulars.	Camp.	
1st	France	Regulars.
2nd	France	Regulars.
3rd	Greene, N. C.	Regulars.
4th	Greene, N. C.	Regulars.
5th	Logan, Texas	Regulars.
6th	McClellan, Ala.	Regulars
7th	MacArthur, Texas	Regulars.
8th	Fremont, Cal.	Regulars.
9th	Sheridan, Ala.	Regulars.
10th	Funston, Kan.	Regulars.
11th	Meade, Md.	Regulars.
12th	Devens, Mass.	Regulars.
13th	Lewis, Wash.	Regulars.
14th	Custer, Mich.	Regulars.
15th	Logan, Texas	Regulars.
16th	Kearny, Cal.	Regulars.
17th	Beauregard, La.	Regulars.
18th	Travis, Texas	Regulars.
19th	Dodge, Iowa	Regulars.
20th	Sevier, S. C.	Regulars.
National Guard:		States From Which Drawn.
26th	Devens, Mass.	New England.
27th	Wadsworth, S. C.	New York
28th	Hancock, Ga	Pennsylvania.
29th	McClellan, Ala.	New Jersey, Delaware, Virginia, Maryland, District of Columbia.
30th	Sevier, S. C.	Tennessee, North Carolina, South Carolina, District of Columbia.
31st	Wheeler, Ga.	Georgia, Alabama, Florida.
32nd	MacArthur, Texas.	Michigan, Wisconsin.

33rd	Logan, Texas	Illinois.
34th	Cody, N. Mex.	Nebraska, Iowa, South Dakota, Minnesota.
35th	Doniphan, Okla.	Missouri, Kansas.
36th	Bowie, Texas	Texas, Oklahoma.
37th	Sheridan, Ohio	Ohio.
38th	Shelby, Miss.	Indiana, Kentucky West Virginia.
39th	Beauregard, La.	Alabama, Mississippi, Louisiana.
40th	Kearny, Cal.	California, Colorado, Utah, Arizona, New Mexico.
41st	Fremont, Cal.	Washington, Oregon, Montana. Idaho, Wyoming.
42nd	Mills, N. Y.	Various States.
National Army:		
76th	Devens, Mass.	New England, New York.
77th	Upton, N. Y.	New York City.
78th	Dix, N. J.	Western New York, New Jersey, Delaware.
79th	Meade, Md.	Northeastern Pennsylvania, Maryland, District of Columbia.
80th	Lee, Va.	Virginia, West Virginia, Western Pennsylvania.
81st	Jackson, S. C.	North Carolina, South Carolina, Flordia, Porto Rico.
82nd	Gordon, Ga.	Georgia, Alabama, Tennessee.
83rd	Sherman, Ohio	Ohio, Western Pennsylvania.
84th	Zachary Taylor, Ky.	Kentucky, Indiana, Southern Illinois.
85th	Custer, Mich.	Michigan, Eastern Wisconsin.
86th	Grant, Ill.	Chicago, Northern Illinois.
87th	Pike, Ark.	Arkansas, Louisiana, Mississippi, Southern Alabama.
88th	Dodge, Iowa.	North Dakota, Minnesota, Iowa, Western Illinois.
89th	Funston, Kan.	Kansas, Missouri, South Dakota, Nebraska.
90th	Travis, Texas	Texas, Oklahoma.
91st	Lewis, Wash.	Alaska, Washington, Oregon, California, Idaho, Nebraska, Montana, Wyoming, Utah.
92nd	Funston, Kan.	Colored, Various States.
93rd	Stuart, Va.	Colored, Various States.

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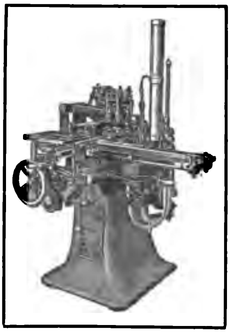

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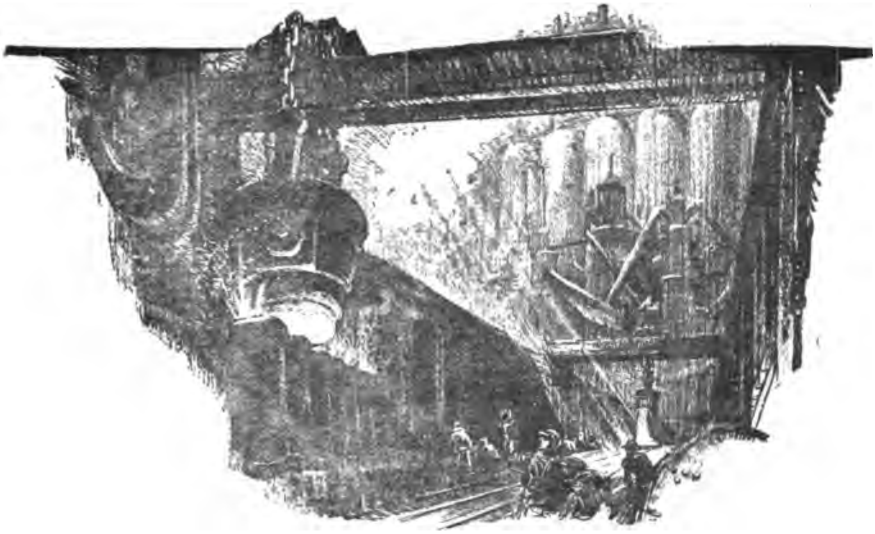

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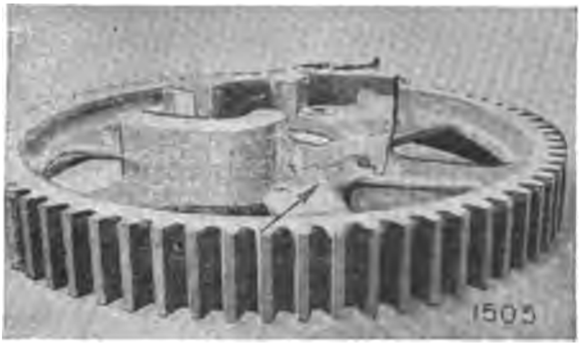

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